

ABSTRACT

Title of Dissertation: THE GROWTH OF INNOVATION
COMMUNITIES: COMMUNITY ECOLOGY
AND DYNAMIC STRUCTURES

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IT innovations are enabling transformational change in many aspects of the economy and society, and can dramatically transform the way people live and organizations operate. The success and development of IT innovations depends on sustained investment and yet IT innovations are subject to rapid changes, significant uncertainty, and high risk of failure. As some IT innovations, such as thin-clients and specialized business programming languages, disappear; others, such as Customer Relationship Management (CRM) systems, become widely used. A lesson learned is that the development of successful IT innovations not only relies on inventing new technologies, but also on providing moderate deployment and sustained support. More importantly, the premise of developing successful IT innovations requires us to understand how, when, and in what context IT innovation occurs. Innovation

communities and the participants within them are an important part of unpacking this complexity, as participants in the innovation communities constantly contributing to providing supports for developing IT innovations. Therefore, promoting and fostering successful IT innovations is dependent on the ability to support the development of IT innovation communities. Against this backdrop, using theories from sociology, information systems, and organizational studies, this dissertation focuses on two underexplored aspects of IT innovation community: ecology of IT innovation community and the dynamics of community structure.

This dissertation fills a gap in prior research by applying organizational ecology theory to a mature IT innovation (CRM) at a community level, to explain the ecological evolution of an IT innovation and dynamic structural context of its associated community. Empirical studies were conducted to test hypotheses regarding ecological and network impacts. The study extends organizational ecology theory by considering the consequences of classic ecological forces (legitimation and competition) on multiple populations of organizations at a community level. Analysis of a longitudinal sample of 286 news articles from 1998 to 2007 suggests that the dynamics of the CRM innovation community are in part shaped by the entry rates of organizations participating as technology providers and adopters, and organizational entry rates are affected by ecological forces. Specifically, organizations' decision to participate in the CRM innovation community depended on two ecological forces: (1) legitimation of CRM attracted organizations to enter the CRM innovation community; (2) competition for resources deterred such entries.

Additionally, this study tested the impact of dynamic community structure on organizations' entry in an innovation community. To test if the network structure of the community was associated with a higher rate of entry by organizations participating as CRM technology providers, a network metric for community structure, scale-freeness, was added in classic density-dependence model. The results suggest that, beyond legitimation and competition, structure of the community that can utilize resources efficiently was linked to higher rate of entry by organizations participating in the CRM innovation community as technology providers.

Overall, this dissertation brings organizational ecology theories of IT innovation from the population/industry level to the higher, community level where multiple populations/industries engage and adds additional insights to the repertoire of theories of IT innovation communities. In particular, this dissertation adds an organizational ecology explanation to understanding the evolution of IT innovation communities, recognizes the distinct populations and demonstrates their contributions to shaping the dynamics of innovation communities, and opens up new ways of thinking about how the network structure of the community interacts with organizations' decision to enter the community, and affects the overall development of the IT innovation communities.

THE GROWTH OF INNOVATION COMMUNITIES: COMMUNITY
ECOLOGY AND DYNAMIC STRUCTURES

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I still remember the day when I received the PhD program offer letter in December, 2012. It was the day when I started my academic journey and made my child dream come true. Five years later, as I am close to the end of my PhD study, I gradually understand what my advisor Professor Brian Butler meant about perseverance being important for succeeding in the academia. His perseverance has set a good example for me and guided me throughout my PhD study. However, I do not think perseverance alone is enough. Beyond perseverance, tremendous help from all people at our iSchool is equally important. I would not have made it without them.

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Chapter 1: Introduction

IT innovations are enabling transformational change in many aspects of the economy and society. The landscape of innovation is also changing as numerous processes, products, and services are digitized or moved to the cloud (Bharadwaj et al., 2013). As a result, traditional industry boundaries are being blurred and broken. For example, firms typically from outside the automotive industry are now offering novel devices, networks, services, and content working on the computing platform of new cars (Yoo et al., 2010). In developing of innovative products or services, the tasks of developer and customer are merging on multi-sided digital platforms (Henfridsson & Lindgren, 2010; Tan et al., 2015). Meanwhile, the roles of developer and adopter are increasingly inter-connected within the globally connected networks (Chesbrough, 2012). Navigating in this complex and dynamic landscape requires us to address a fundamental challenge: how, when, and in what context IT innovation occurs.

From the innovation adoption and implementation perspective, Information Systems (IS) scholars have thoroughly studied a wide array of IT innovations (Agarwal & Prasad, 1997; Fichman, 2004; Taylor & Todd, 1995; Thong, 1999). Regarding the evolution and development of IT innovation, Technology and Innovation Management (TIM) research has a long tradition of investigating innovation evolution patterns (Hargrave & Van De Ven, 2006; Ruttan, 2001). These prior research findings have important implications for understanding the diffusion, adoption and development processes of IT innovations.

Another aspect of IT innovation research considers the communities associated with the IT innovations. Some theoretical work has suggested that the development of an IT innovation is shaped by the inter-organizational community around it and all participants from different sides involved in that community matter (Swanson & Ramiller, 1997). From this perspective, community ecologists further argued that the inter-organizational relationships associated with participants also contributed to shaping the development of the community (Astley, 1985; Freeman & Barley, 1990; Rao, 2002). A wide variety of empirical studies have examined and explained how such communities developed and evolved over time (Barnett, 1990; Brittain & Wholey, 1988; Carroll, 1981; Nielsen & Hannan, 1977). However, these community ecology studies usually treated each community as a whole and explained the community dynamics in aggregate.

In addition, former empirical examinations tended to study innovations from only one perspective (Frambach et al., 1998; Weigelt & Sarkar, 2009), as prior work treated providers and adopters separately. For example, IS research on innovation diffusion is focused on the adopter perspective of innovations, assuming the provider perspective of innovations is plentiful. Similarly, TIM research concentrates on the design and development of innovations, with much less attention to their actual use. Over time, mainstream innovation research has treated innovation development and diffusion separately and this division has been increasingly challenged by researchers in both disciplines (Jeyaraj et al., 2006). In IS, the rise of Design Science is shifting focus to the design and evaluation of technological artifacts (Hevner et al., 2004), often hidden in surrogate measures in traditional innovation diffusion research

(Orlikowski & Iacono, 2001). In TIM, research has suggested that innovative design ideas often come from the users of innovations (Von Hippel, 2007). Hence, a lesson learned in prior literature is that both development and diffusion of an innovation, both its creation and adoption, both its design and use matter.

Together, these two limitations in existing research suggest that there is a need for research considers explaining the internal dynamics and structure of a community which involves participants from different sides (e.g., supply and demand). As organizing vision theory suggests, promoting and fostering successful IT innovations is dependent on the ability to support the development of IT innovation communities (Swanson & Ramiller, 1997). In the context of an IT innovation community, participants who play different roles such as developers (supply side) and adopters (demand side) work together to make sense of an IT innovation and correspondingly form different community based on inter-organizational relationships (e.g., competition between developers and adoption relationship between developer and adopter) through various interactions. However, there is limited work explaining how these distinct participants (e.g., developers and adopters) and their associated inter-organizational relationships within IT innovation communities affect the development of the communities.

Ecology theory is a promising framework for the development of a holistic theory of IT innovation community. The framework of ecology has been conceptualized as aggregations of inter-dependent actors that support activities within a boundary (Assessment, 2003). The idea of ecology theory has been applied for innovation research at organizational (Adner, 2006; Autio & Thomas, 2014; Woodard

& Clemons, 2014), industry (Van de Ven & Garud, 1993), and national (Fukukda & Watanabe, 2008) levels. Researchers adopting this perspective have the potential to break new ground in innovation research because they examine factors and actors (often treated separately in previous research) and their interdependencies together.

The goal of this dissertation, therefore, is to launch a research program drawing from ecology theory to provide a more comprehensive picture of the communities surrounding IT innovations. This dissertation takes the "eco" in innovation ecological systems seriously by focusing on examining and understanding the dynamics of an innovation community which is comprised of multiple inter-dependent populations of organizations with interests in producing and/or using a focal innovation. Specifically, a theory of innovation community ecology, which considers the aspects of legitimation and competition within each distinct population as a part of the innovation community dynamics, is proposed to characterize the ecology and dynamics of such innovation community. Overall, this dissertation aims to address the research question: *How do the composition and structure within an IT innovation community shape its subsequent development?* Empirical studies are conducted to examine both impact of organization ecological context at community level and dynamic innovation community structure on the development of an IT innovation community.

The dissertation is organized as follows: Chapter 2 describes the relevant literatures, starting with reviewing of organizational ecology theory, developing and extending the utility of the theory at community level. Chapter 3 applies the organizational ecology theory to IT innovation communities. Then related network

theory is reviewed and a network metric, scale-freeness, is introduced to characterize the dynamic structure of a community. Finally, hypotheses regarding the ecological effect and dynamic community structure on organizational entries are developed based on the theoretical work review. Chapter 4 describes the detailed methods used. In particular, the density-dependence model in organizational ecology theory is used to examine the dynamics of multiple populations within an innovation community. Chapter 5 reports the evolution of the innovation community and network structure of the innovation community, and tests the proposed hypotheses in the preliminary study. Chapter 6 documents additional analysis to address the major limitations in the preliminary study (e.g., multiple data sources and application of density-dependence model to innovation community based on discourse data). Sensitivity analysis with a richer dataset is conducted to check the validity of ecological measures (legitimation and competition) captured by organizational density in the context of innovation community. Then, hypothesis regarding the impact of community structure on organizational entries is tested. Specifically, a network measure, scale-freeness, is added in the density-dependence model to characterize the impact of community structure on organization's ongoing participation decisions in the community. Finally, empirical findings for additional analysis are reported. Chapter 7 summarizes the overall findings, discusses the implications of the findings for research and practice, and concludes with a discussion of possible directions for future research.

Chapter 2: Theoretical Background

This chapter first reviews organizational ecology and community ecology theory. Then, I describe the primary differences between organizational ecology and community ecology and explain their complementary features to study the dynamics of IT innovation communities.

2.1. Organizational Ecology

Organizational ecology theory is originally borrowed by organizational sociologists from biology to describe the evolution of organizations (Hannan & Freeman, 1977). Organizational ecology is a theoretical approach to understanding the "forces that shape the structures of organizations over long time spans" (Hannan & Freeman 1993, p. xi). The ensuing paradigm of organizational ecology, as Baum and Amburgey (2002) reviewed, "aims to explain how social, economic and political conditions affect the relative abundance and diversity of organizations and to account for their changing composition over time" (p. 304). Research in organizational ecology primarily aims to address three issues. First, it seeks to explain the diversity within populations of organizations. Second, organizational ecology scholars examine the adaptability of organizations to the environment uncertainty. Third, they work to understand factors affecting the emergence and disappearance of organizations.

In early research, organizational ecology studies mainly examined the changes and variability of organizations at a population level over time and had two research themes. One theme focused on the creation of new organizations and their death. The other theme focused on populations of organizations with heterogeneous attributes. The approach of these themes, however, fails to explain the diversity of organization

within a population and pays little attention to organization decision makers' strategic choices.

The primary argument of organizational ecology is that organizations that best fit the environment are likely to dominate. So, natural selection process indeed selects out many unfitted organizations, leaving fewer organizations in the pool with less diversity. Therefore, rather than explaining the diversity of organizations, early organizational ecology theory is more comfortable to explain the homogeneity of organizations and limits its explanation for diversity within a population.

Additionally, early organizational ecology studies treat the role of environment as the key factor to affect the structure of organizations and seek to explain how various environment settings could affect the distribution and diversity of organizational forms in such environment contexts (Baum & Oliver, 1996; Carroll & Hannan, 2000; Drazin & Schoonhoven, 1996; Lomi & Larsen, 1996). These studies, however, did not consider the impact of internal organizational characteristics and managers' attempt to strategically adapt.

2.2. Two Primary Themes in Organizational Ecology

In organizational ecology theory, an environment can be described in terms of factors such as the presence of other organizations and more broadly populations, resources needed to support those organizations' survival, and availability of the resources. In organizational ecology, population ecology is a primary perspective which considers organization as a unit of analysis and explains the relationship between organizations and their associated environmental settings. Over a long time, organizational ecology researchers argue that the pattern of organizations is affected by a natural selection process and organizations have low flexibility to adapt to environmental changes as they grow larger and older (Hannan & Freeman, 1986; Hannan & Freeman, 1993). The environment eliminates populations of organizations that are not suitable for the environment and select the most suitable ones for survival. Therefore, each environment accommodates a most suitable corresponding organizational form. Similarly, different environment settings accommodate different types of organizations, so the diversity of organizations is determined by the characteristics and nature of changes in the environment or the number of competing organizations in a population.

Early research of organizational ecology pays little attention to the ability of organizations to adapt environments (Amburgey & Rao, 1996). The possibility of an organization's survival ability is argued to depend on the age and size of an organization (Péli et al., 1994; Ranger-Moore, 1997). Ranger-More (1997) argued that well-established firms are more adept at taking advantages of resources in the environment, and meanwhile these firms are better at competing for resources than

new entrants given their incremental capabilities developed over time. Therefore, new firms will be more likely to die than well-established ones when they enter in a population. The mortality rate reaches the highest point when new organizations are found and this pattern will decrease with the age of organizations growing in a population. In addition, large firms have higher survival chance as they have access to more resources compared to small firms that have access to limited resources, and this argument has been supported by empirical studies showing such patterns (Barron et al., 1994). Overall, these studies focused on examining and explaining the founding and mortality rates of populations.

Later, researchers observed that organizations have developed capabilities to adapt to environmental turbulence and uncertainty over time, and thus they considered both adaption and selection processes matter (Bruderer & Singh, 1996; Singh & Lumsden, 1990). Then the focus of organizational ecology studies switched from focusing on determinants of founding and mortality rate to examining determinants of change in organization forms (Amburgey & Rao, 1996). Empirical studies have found that both selection and adaption process matter in the evolution of organizations. For example, a longitudinal study of gasoline retail industry (Usher & Evans, 1996) showed that gasoline managers constantly attempted to change the structure of organizations for survival in the presence of environmental changes. Their results implied that only if the transformations were favored by the environment, such transformations were likely to be adopted by organizations. And, however, if the organization changes disrupt the institutional routines to a large degree, the likelihood of failure increases (Amburgey et al., 1993).

Overall, the history of organizational ecology theory and research can be categorized into two themes: ecological and demographic processes. Table 2.1 summarizes the selected sample studies regarding ecological and demographic processes.

Table 2.1 Sample Studies in Organizational Ecology¹

Reference	Key Concepts	Key Variables	Key Findings and Predictions	Contributions	Method and Sample
<i>Ecological process: Niche width</i> Swainathan, 1995	Resource partitioning	Concentration of mass producers	Concentration among mass producers affect the founding of specialist wineries	When controlling for alternative processes, the resource partitioning model is supported	Negative binomial regression Farm wineries
<i>Ecological process: Density dependence</i> Hannan et. al., 1995	Density dependent legitimation and competition	Population density	The effects of legitimation are broader in scope than competitive effects	Effects of density vary by geographic scope	Event count analysis Automobile firms
<i>Demographic Process: Age and size dependence</i> Ranger-Moore, 1997	Senescence Obsolescence	Age Size Environmental Change	Liability of aging is driven by obsolescence	Competitive intensity moderates effects of change on failure	Event history analysis Life insurance companies
<i>Demographic Process: Rates of change</i> Amburgey et al., 1993	Organizational momentum Change history	Organizational change Failure	Relationship between and change and failure is dependent and age is the moderation	Structural inertia has two elements: resistance to change and momentum for change	Event history analysis Newspaper

¹ Table 2.1 is adapted from "Companion to Organizations" edited by Baum, J. A., & Rowley, T. J. (2002).

2.2.1. Ecological processes

Ecological processes focus on selecting mechanisms and how those mechanisms are affected by the larger context in which populations exist. There are two primary themes in organizational ecology that consider ecological processes: niche width theory and population density dependence.

Niche width theory explains how different organizations survive under natural selection process. The survival of organizations requires resources such as technical employees, expertized consultants, and potential customers. Such resources come from the environments where organizations reside and different components of resources are available in different contexts (Amburgey & Rao, 1996; Freeman & Hannan, 1983; Hannan & Freeman, 1986; Hannan & Freeman, 1977). A niche refers to the clusters of resources that are available to support organizations' survival. Niches that support different populations depend on the resources. Therefore, organizational diversity arises because some organizations are better able to survive and thrive in some niches under the large context.

The survival and thriving of organizations is dependent on the organizational structure that fit the environmental pattern in the natural selection process (Hannan & Freeman, 1986; Hannan & Freeman, 1993). In regard to the organizational structure, there are two forms presenting in niche width theory: general form (also referred as generalist) and special form (also refereed as specialist). The generalists have a broader niche and rely on a wide range of resources in the environment for survival, so when these organizations are exposed to rapid and prolonged environmental changes, they are more likely to survive (Freeman & Hannan, 1983; Hannan &

Freeman, 1986). On the other hand, specialists have a narrower niche and take advantage of the environment to a greater degree. Therefore, specialists usually fit well with the environment unless rapid and uncertain environmental changes occur. When specialists are exposed to unstable and rapid changing environments, they are less likely to survive (Freeman & Hannan, 1983; Hannan & Freeman, 1986). For example, the resource partitioning model proposed by Swainathan and empirical results of farm wineries' development over 50 years suggested the survival of different specialists (Swaminathan, 1995). The results implied that in concentrated markets with few generalists, specialists can exploit resources sufficiently without engaging in direct competition with generalists. Therefore, the niche width theory challenges the prediction of classical contingency theory: generalists who are able to resist the rapid changes and correspondingly spread their risks are always favored by uncertain environment. The diversity of organizational form is actually determined by the characteristic of different environmental settings in different market niches (Amburgey & Rao, 1996). Availability of resources & fitted organizational structure is a necessary condition for organizations' survival, but the presence of other similar organizations in one population complicates the picture. This is because resources are limited, and the number of organizations that can use the same pool of resources is necessarily limited. This leads to the competition for critical resources in one population.

In population density dependence model, the focus is the effects of competition on organizations' survival and variation in population arose by competition. Variation in organizational population is signaled by two primary

elements: organizational entry rate (at which organizations enter or are founded in the population) and exit rate (at which organizations fail or leave the population).

Variation occurs when organizations enter or exit from a population (Rao & Singh, 1999). Organizational ecologists argue that the degree of competition organizations face affect their relationships in the natural environments. Organizations have to compete with other organizations for limited resources so that they can survive and grow. The environment determines the most suitable organizational forms to survive and eliminates the organizational forms that are unsuitable in such conditions.

Organizations that rely on the same environment must find ways to coexist. For example, the presence of similar organizations provides legitimacy for that type of organization (Meyer & Rowan, 1977) and opportunities for them to learn from each other (Ingram, 2002). Meanwhile, similar organizations relying on a common pool of resources force them to compete for the ultimately finite resources they need. As a population of similar organizations emerges, increasing legitimacy attracts new organizations and reduces the chances of failure for those already in the population. As the population grows, increasing competition discourages entries and makes incumbents more likely to fail. For example, Hannan et al. (1995) empirically examined the ecological processes of automobile industry in Europe by applying population density dependence model. Their results supported the hypotheses that legitimation has a positive effect on attracting new organizations while competition has a negative effect at industry/population level.

While organizational ecology theory has mostly focused on distribution of resources and environmental settings (niche width theory) and competition

(population density dependence), organizational ecologists later began to incorporate theories from other disciplines such as economics and strategic management to examine different environment contexts and multi-level organizational processes (Baum & Oliver, 1996; Drazin & Schoonhoven, 1996; Lomi & Larsen, 1996). For example, Lomi and Larsen (1996) suggested that the variations in local environment could affect the population density (legitimation) and the population density affects the founding and mortality rate of organizations. This study contributed to comprehensively understanding the impacts of environment on the survival of organizations. Baum and Oliver (1996) demonstrated that the effect of competition in ecological process was stronger in local areas than at higher geographical level (e.g., rural areas). Their results suggested that ecological processes worked differently at different levels of analysis. But all these studies are still about resources distribution and competition.

What about the adaptability of organizations and organizations' willingness to change for survival? Bruderer and Singh (1996) argued that organizations attempted to change the environmental settings to their favor regardless of their different capability to learning and adapting. Therefore, in contrast with prior organizational ecology work, researches have treated the ecology perspective and adaptation perspective as complementary. The decision of organizations on adaptation is affected by environmental selection, while organizations' different corresponding adaptation strategies in turn affect the impact of environment (Levinthal, 1991; Scott & Davis, 2015). The adaptability of organizations and their willingness to change is reviewed in demographic processes.

2.2.2. Demographic processes

Demographic process in organizational ecology primarily argued that no organizations exist prior to its founding, so the founding process of organizations is determined by the attributes of a population. However, existing or established organizations have histories and structures that can affect the rates of change and failure. Hannan and Freeman (1984) argued that the key to organizations' survival is reproducibility of activities, which is achieved through institutionalization and routinization. Reproducibility increases with age. Organizational ecologists, therefore, conducted research to examine the effects of these characteristics of organizations (e.g., size and age of organizations) on rates of organizational change and failure. One of their primary finding is that organizational change and failure was dependent on and moderated by age and size. For example, Ranger-Moore (1997) empirically examined the relationships among age of organizations, size of organizations, and organizational failure in an archival event history study of 154 New York life insurance companies during 1813 -1985. The empirical results also confirmed that both age and size in terms of incremental adaptability of organizations affected organizational failure when moderated by environmental stability.

Organization's willingness to change is another aspect that organizational ecologists concentrate on in demographic processes. With regard to this, structure inertia theory (Hannan & Freeman, 1984) is proposed to explain the process of organizational change from several perspectives. Structure inertia theory argued that well-established organizations have more formalized structures, standard routines, institutionalized power distribution, dependencies and commitments, and the inertia

of organizations increase with the age of organizations(Hannan & Freeman, 1984). As organizations grow, the size and age of organizations allow organizations to benefit from current environment and thus further reduce their will to change. Two important elements in structure inertia theory (resistance to change and momentum for change) was later found to affect the willingness of organizational change and failure by an empirical event analysis on the 1011Finnish newspapers over 193-year period (Amburgey et al., 1993).

2.3. Critique of Organizational Ecology

The history of organizational ecology is colorful, yet its weakness is also well known for being environmentally deterministic. Most of the studies treat the role of environment as the key factor to affect the structure of organizations, without considering the impact of internal organizational characteristics and managers' attempt to strategically adapt (Baum & Oliver, 1996; Carroll & Hannan, 2000; Drazin & Schoonhoven, 1996; Lomi & Larsen, 1996). Early organizational ecology studies pay little attention to the adaptation perspective which suggests the diversity of organizations is in partial the outcome of organizations' willingness to change (e.g., organizational forms and structures) for survival in different environmental settings. All in all, early organizational ecology perspective focuses on the impact of environment selection more than the role of organizational adaptation.

However, another factor not considered by traditional organizational ecology theory is the competitions & interactions between populations (Amburgey & Rao, 1996; Astley, 1985; Baum & Rao, 2001; Hunt & Aldrich, 1998; Singh & Lumsden, 1990). Indeed, a wide array of studies suggested competition exists across populations too (Baum & Singh, 1994; Singh et al., 1993; Wang et al., 2013). Similar as organizations need resources to survive and grow, populations have to compete with other populations that need similar resources (Hannan & Freeman, 1993; Rao, 2002). When the available resources are limited, the potential growth of a population is restricted. As a result, the growth of one population will often decrease the growth of others (Barron et al., 1994; Ingram & Inman, 1996). This phenomenon happens when organizations in different populations need similar resources to survive, but the

amount of resources is not enough to support all organizations in their own populations, and at this point organizations have to compete with each other beyond population level. There are several studies suggesting that the level of competition increases when organizations seek similar resources (Barnett & Carroll, 1987; Baum & Mezias, 1992). Moreover, regarding the effect of resources similarity on competition, researchers have found that the degree of resources similarity will increase the potential for competition (Baum & Oliver, 1996; Podolny et al., 1996). Also, in response to various organizational ecology studies that have been done at population level, Astley (1985) criticized population ecology for failing to explain how populations initially develop, and thus favored an ecology theory at the community level. The community ecology will be further reviewed in the next section.

2.4. Community Ecology

Community ecology is a theoretical approach that considers the rise and fall of populations as basic units of evolutionary change (Astley, 1985). Community ecology aims to examine and explain how similar and dissimilar populations that comprise communities interact with each other and how they collectively adapt to the environment (Rao, 2002). Community ecology approach extends organizational ecology theory by complementing population ecology approach which addresses organizations as unit of evolutionary change.

Community ecology describes that sets of organizations are bound by ecological ties of commensalism and symbiosis which consequently coevolve with each other and their environment (Greve, 2002; Rao, 2002). Symbiosis is defined as objects or forms that have dissimilar functions with inter-dependent presences on each other (Hawley, 1950). In community ecology, symbiosis (collaboration) refers to arrangements where populations that occupy different niches benefit from the presence of each other. Commensalism (competition), on the contrary, is defined as objects or forms that have similar functions with inter-dependent presences on each other (Hawley, 1950). In community ecology, commensalism refers to potential competitions between interacting populations. In general, community ecologists argued that the outcomes of organizations in any one population are fundamentally intertwined with those of organizations in other populations that belong to the same community system (Baum & Rao, 2001; Rao, 2002). Research in community ecology involves examining the creation and demise of populations of organizations that affect the stability of a community.

2.4.1. Definition of community

Just as there are different views on what comprise a population among population ecologists (Aldrich, 1999; Baum & McKelvey, 1999; Hannan & Freeman, 1993; McKelvey, 1982; Rich, 1992; Romanelli, 1989), the definition of community varies as well. For this study, a definition of community was created based on reviewing different dimensions of the core characteristics of communities suggested by organizational ecologists (Hannan & Freeman, 1984). As Hannan and Freeman (1984) proposed, several major differences existed between the core and peripheral attributes of organizations, and in community ecology, there are four core dimensions of organizations which have been used by researchers to define community. Table 2.2 summarized the selected sample articles using such dimensions of organizations to define community.

A variety of community definitions have been used by researchers to study the effects of community ecology on populations. Some studies considered that the community was organized in terms of a stated goal. For example, Nielsen (1977) and Carroll (1981) defined the entire US education system as a community. Other studies treated a well-structured industry as a community. For instance, Haveman (1997) applied community ecology approach to study the US saving and loan industry. Technology is another dimension that community ecologists used to characterize a community. To illustrate, the entire US telephone system (technology infrastructure and skilled people around that technology) was refereed as a community in the prior studies (Barnett, 1990; Barnett & Carroll, 1987). Last, Baum and Singh (1994)

studied the US day care organizations, and their definition of community focused on the market strategy regulated by the types of customers and clients.

Table 2.2 Communities Definitions and Selected Sample Articles²

Alternative Community Definitions	Example Communities
<i>Stated goal</i> Community is defined based on a particular stated goal	<i>Education-oriented community</i> US education system (Nielsen & Hannan, 1977; Carroll, 1981)
<i>Authority relations</i> Community is defined based on the structure of an industry	<i>Authority structured and hierarchical community</i> US Saving and loan industry (Haveman & Rao, 1997)
<i>Core technology</i> Community is defined by technology infrastructure, and the skills and knowledge of people around that technology	<i>Technology-oriented community</i> US telephone system (Barnett & Carroll, 1987; Barnett, 1990)
<i>Market strategy</i> Community is defined by the types of customers and clients	<i>Marketing-oriented community</i> US day care organizations (Baum & Singh, 1994)

Another way that community definitions have varied relates to the level of analysis. For instance, Korn (1994) defined community at the level of a national economy in Canada, while Saxenian (1994) defined community more narrowly based on those closely related populations in region of Silicon Valley. Additionally, a community can also be referred to a combination of single region and industry like Pennsylvania phone companies (Barnett & Carroll, 1987).

Overall, in community ecology study, a set of populations may refer to a national, regional, or global economic system (Korn & Baum, 1994), or may be constricted to a particular geographic area (Saxenian, 1994) (e.g., Silicon Valley), or may be built around on a technical feature (e.g., telecommunication community,

² Table 2.2 is adapted from "Companion to Organizations" edited by Baum, J. A., & Rowley, T. J. (2002).

Table 2.2). Therefore, the definition of community for a community ecology study may vary based on the characteristics of populations and the level of analysis.

In this dissertation, community is considered to be comprised of populations that involving using and adopting a core technology and related infrastructures. The community is built around the technology through the participation of various populations and associated activities. Additionally, the level of analysis in this dissertation primarily focuses on North America given the accessibility of available data.

2.4.2. Community dynamics, evolution and structure

The dynamics and evolution of a community involves several aspects: variation within new populations and forms, selection processes shaped by inter-organizational relationships such as collaboration and competition between constituent populations, and the retention of established populations (Baum & Rao, 2001; Baum & Singh, 1994; Greve, 2002; Hunt & Aldrich, 1998; Rao & Singh, 1999).

New populations are formed when entrepreneurs develop new organization forms that use resources in novel ways. Just as variation in organizational forms in population ecology creates diversity (Hannan & Freeman, 1986), variations among a community's component (e.g., population) gives rise to community dynamics (Rao & Singh, 1999). Generally, community dynamics are arose by population variations when new organizational forms are to be created by entrepreneurs within communities. Technology transformations are used to disrupt the prevalent social order in this process. Community dynamics occur when organizations that belong to

different populations join in or exit from a community (Hannan & Carroll, 1992; Rao & Singh, 1999). The rise and fall of organizations that belongs to different populations within a community shapes the variation in each of their own populations and together affect how a community develops over time. Specifically, community dynamics are signaled by two primary elements: entry rate of populations of organizations (at which populations of organizations enter or are founded in the community) and exit rate of populations of organizations (at which populations of organizations fail or leave the community). Variation in each population that comprises a community contributes to shaping the population variations in that community, and ultimately the community dynamics.

Population variation is one of the factors that affect community dynamics. In the selection of populations within a community, inter-organizational relationships (e.g., collaboration and competition) also affect community dynamics when populations interact with each other (Baum & Rao, 2001). For example, Astley (1985) argued that the collaboration and competition allow communities to become functionally integrated systems, in which populations interact and exchange resources more with each other than directly with the environment. These inter-organizational relationships enact a network within a community that shapes a hierarchical structure in the community over time (Freeman & Barley, 1990; Greve, 2002; Gulati & Gargiulo, 1999; Rao, 2002; Singh & Lumsden, 1990). Further, as Hannan and Freeman (1993) argued, the growth of one population in a community is affected not only by direct interactions with other populations, but also by their indirect interactions and feedback processes. Therefore, interactions among populations for

resources affect the development of each population within a community. Overall, the viability of organizations in certain forms may be fundamentally intertwined with those of organizations in different forms through various inter-organizational relationships if they reside in the same community.

As a community evolves over time, the retention effect of established populations is observed when the internal structure of a community (as a closed system with limited populations) is disrupted (Baum & Rao, 2001; Greve, 2002; Rao, 2002). This is because there have been a limited number of niches in the community. Within the community boundary, different niches are occupied by different populations which are saturated over time, and correspondingly competitions will keep new organizations from entering those populations. Therefore, when the size and structure of each population keeps balanced against the needs of other populations in the community, no new populations can gain legitimacy or enter the community without impairing the established populations (Baum & Rao, 2001; Greve, 2002; Rao, 2002). Meanwhile, established populations are also reluctant to welcome the entry of new populations given the competitions for limited available resources in the community.

To conclude, in regard to the community dynamics and structure detailed above, a wide variety of research work has been done to suggest that different roles (e.g., technology provider and adopter) that each population plays in a community in part shape the development of the community (Sun & Wang, 2012; Swanson & Ramiller, 1997; Wang & Ramiller, 2009) and the inter-organizational relationships (e.g., collaboration and competition) embedded in each role affect the growth of such

community (Astley, 1985; Freeman & Barley, 1990; Greve, 2002; Rao, 2002; Singh & Lumsden, 1990). Therefore, if we are to fully understand the community dynamics and structure, it is necessary to describe the characteristics (e.g., size and structure) of each population and how each population develops and interacts with other populations within the community.

2.4.3. Related work of community ecology

In study of community ecology, a wide variety of quantitative studies have been conducted to examine the effects of population densities on the rates of foundings, growth and failure. In the early community ecology work, for example, Nielsen (1977) analyzed the interactions among populations in the primary, secondary, and tertiary educational sectors that comprise the US national education community systems.³ Their results suggested the existence of a positive hierarchical interdependence across primary, secondary, and tertiary educational sectors. However, community ecologists later argued that the study of community dynamics should consider the relations with all possible interacting populations because the expansion of one population may lead to the reduction of resources for other populations. This argument (and the existence of collaboration and competition among populations) is further demonstrated by conducting an additional empirical analysis within US national education system (Carroll, 1981).

Some other studies examine the birth and death rates of populations in a community built around the technical infrastructures. For instance, Brittain (1988) studied the dynamics of populations in the US electronics components manufacturing

³ Community in Nielsen & Hannan (1977) was defined as all organizations committed to the goal of education.

industry. Their empirical results showed that the birth, growth and death of firms in a community were, to a large degree, shaped by complicated collaboration and competition relationships among organizations. The effect of collaboration and competition on the evolution of a community was further supported in a study of mortality of firms in the telephone industry. Barnett (1990) reported that a collaboration relationship was found when firms were technologically standardized, and competition existed when firms were technologically incompatible or non-complementary.

There are also plenty of qualitative studies having been conducted with interviews and/or archival data to understand how communities cohere around common cultures. For example, a case study was conducted by Saxenian (1994) to compare and understand the evolution of Silicon Valley and Route 128 community. Although these two communities have a similar origins and technologies, the case study result suggested that they evolved differently. The culture and network system of Silicon Valley fostered collective learning and strategic collaboration among companies for survival, while Route 128 community relied on a small number of relatively top-down integrated companies with few relationships (e.g., collaboration).

Table 2.3 summarizes sample studies of community ecology using both quantitative and qualitative analysis.

Table 2.3 Sample Studies in Community Ecology⁴

Reference	Key Concepts	Key Variables	Key Findings	Key Contributions	Method and Sample
Nielsen & Hannan, 1977	Collaboration Competition	Expansion rate Inter-sectorial dependence	Positive interdependence across sectors	Positive serial interdependence	Time series US education system
Carroll, 1981	Collaboration Competition	Expansion rate Inter-sectorial dependence	Existence of collaboration and competition relationships	Specification of inter-population relationships	Time series US education system
Brittain & Wholey, 1988	Collaboration Competition	Death, birth, and growth rates of populations of organizations	Existence of collaboration and competition relationships	Inter-organizational relationships among market population of organizations	Event history analysis Electronic components industry
Banett, 1990	Ecology of a technical system	Vital rates of firms	Existence of collaboration and competition relationships	Interactions among populations are moderated by technological complementarity and incompatibility	Event history analysis US phone industry
Saxenian, 1994	Collaboration	Collaboration and partnerships	Culture-oriented segmentation and collaboration	Comparative analyses of communities	Case study Silicon Valley and Route 128

⁴ Table 2.3 is adapted from “Companion to Organizations” edited by Baum, J. A., & Rowley, T. J. (2002).

2.4.4. Critique of community ecology

Despite the impressive accumulation of both quantitative and qualitative work, the limitations of community ecology studies with respect to the nature of community and functionality of organization within communities have been debated for decades.

In the history of community ecology research, early work has demonstrated the existence and effect of collaboration and competition among population of organizations within communities (Barnett, 1990; Brittain & Wholey, 1988; Carroll, 1981; Nielsen & Hannan, 1977). Later, Barnett (1994) suggested that a community could be defined as populations of organizations united through bonds of collaboration and competition. This argument is based on prior studies which have demonstrated the existence of collaboration and competition relationships within and among populations of organizations. However, as the definitions of community in most community ecology work are based on the four core features of organization suggested by Hannan and Freeman (1984) (Table 2.2), there are few studies that focuses on the ecological interactions among populations and industries. Most of the community ecology studies aimed to address interaction effects within populations, and more recently at the boundaries between populations (Hannan, 2010). In addition, research work also indicated other inter-organizational relationships may also contribute to advancing the growth of a community (Astley, 1985; Freeman & Barley, 1990; Rao, 2002). For example, a community ecology study of cloud computing suggested that, in addition to collaboration and competition relationships, other inter-

organizational relationships such as adoption and research may matter for the evolution of a community (Sun & Wang, 2012).

Organizational theorists have raised questions about the nature of communities (Amburgey & Rao, 1996; Baum & Rao, 2001). For example, DiMaggio (1994) argued about the composition of community and suggested that populations were not the right unit of analysis, and hence studies of community ecology were unlikely to be of great importance for understanding the evolution of organizations. The central argument relied on the reason that social processes and interactions among organizations, to some extent, effaced the boundaries of populations. As a result, many communities which were consisted of some small populations blurred by organizational activities are not suitable to capture the effect of collective actions (Baum & Rao, 2001; Rao, 2002). Therefore, if community is conceptualized from a broader perspective (DiMaggio, 1994) that concentrated on social processes, the study of community ecology will become a study of social phenomenon, and its focus will be no longer organizations and their associated communities. While this argument may be true in some contexts, it could not apply to the innovation community. This is because an innovation community is comprised of distinguished populations that play a variety of roles (e.g., technology provider and adopter are totally different populations) (Swanson & Ramiller, 1997; Wang & Ramiller, 2009), the boundaries of which are not easy to be effaced. Further, as Hannan and Freeman (1984) argued, a group of different populations could be built around a core technical feature and/or technology, and populations that comprise such a community contribute together to shaping the core technical feature and/or technology. Thus, the

activities of organizations are usually effective to characterize the collective actions within such communities.

The functionality of organization within community is another debate lasting for a long time in the community ecology literature. Community ecology studies aim to explain the effects of interdependences within and among population of organizations. However, some researchers argued that strong interdependences and dynamics are the attributes of many physical, biological, and social systems, and they could not apply to organizations (Puccia & Levins, 2013). Therefore, organizations are objectives that do not function (e.g., interact with each other) in a community. In response, other researchers argued that some complex systems can also produce organizations with different features and attributes without natural selection process as biology posits for evolution (Kauffman, 1993; McKelvey, 1999). Further, recent work on innovation community has suggested that populations of organizations do have different functions and they even learned from each other with purpose {Swanson, 1997 #50; Swanson & Ramiller, 2004). As organizations learn from each other, their reflection and experiences can be fed back into the community. As a result, community learns as its members (organizations) learn, in a cycle that builds knowledge on both the organizational and community levels over time (Wang & Ramiller, 2009). In the context of innovation community, not only the populations of organizations are functional, but also the community itself is functional. To fully understand the dynamics of innovation communities, researchers, therefore, need to consider both organizational ecology (population ecology and community ecology) and biology knowledge, synthesize and apply them to innovation communities.

This section summarized the primary argument about community ecology and related work done by researchers to prove the existence of inter-dependence relationships within and across populations and interaction among them on shaping the stability and evolution of a community. Then, limitations of community ecology are elaborated. Finally, critiques of community ecology were discussed with response.

In so far, studies of a wide variety of population ecology and community ecology have been reviewed, their utility, primary differences, and complement will be discussed in the next section.

2.5. Population Ecology and Community Ecology

Two central elements in population ecology are: environment setting and natural selection. Environment setting refers to the presence of other organizations and populations, resources that support organizations to survive, and availability of the resources. Natural selection processes function within the environment to screen out unfit organizations, and organizational forms that best fit the environment are likely to dominate (Hannan & Freeman, 1977, 1993). Specifically, natural selection processes operate within established populations and explains how different organizations survive within populations. Organizations that survive in the population progressively refine and homogenize their forms and structures to adapt themselves to the environments (Astley, 1985; Hannan & Freeman, 1986). However, the theory of natural selection itself does not explain how new populations originate and correspondingly increase the diversity of organizations.

Prior work on population ecology followed the idea of natural selection theory and a variety of organizational ecology empirical studies have been conducted within already established populations (Amburgey et al., 1993; Hannan et al., 1995; Ranger-Moore, 1997). In these studies, population ecology was applied to explain the ecological forces that make organizations more uniform rather than more diverse, without considering how the evolutionary changes were present through the rise of heterogeneous organizational forms in the context of established populations. In addition, as population ecology treats organization as a unit of analysis, the theory could not account for the dynamics (e.g., growth, birth, and death rate) of entire sets of populations.

Given the limitations of population ecology approach for explaining the different outcomes of populations themselves as units of change, Astley (1985) proposed a community ecology approach to account for how new populations originate and considered the rise of heterogeneous organizational forms within a community. Beyond studying the relationships (e.g., legitimation and competition) between organizations within populations, community ecology considers relationships between multiple populations and their interactions in communities. In community ecology, population is treated as the basic unit, which grows, develops and evolves as part of a community. Different populations compete for resources and collaborate by playing complementary functions in a community. Populations in a community are bound by collaboration and competition ties and correspondingly become interdependent (Rao, 2002). These interdependencies allow populations of organizations to shape their forms and structures over time, and eventually organizational forms and structures fittest for the environment are likely to dominate in the communities. If the environment changes, a different structure may dominate as a result of restructured collaboration and competition (Astley, 1985; Freeman & Barley, 1990; Rao, 2002). In this regard, community ecology overcomes limitations of population ecology. This is because community ecology considers the rise and fall of populations as basic units of evolutionary change, and simultaneously is able to explain the ecological forces that produce homogeneity and stability within populations and heterogeneity between populations.

Rather than treating population ecology and community ecology as two separate approaches, they are complementary. A combination of population and

community ecology approach is particularly useful when studying innovation community dynamics. On one hand, a community can be comprised of different populations of organizations (Hannan & Freeman, 1984), and the variation within each population in part shapes the community dynamics. To describe and understand the variation within different populations that comprise a community, population ecology approach is an important part. On the other hand, community ecologists have argued that the interactions (e.g., collaboration and competition) within and among populations of organizations is another force that shapes the growth and development of a community (Astley, 1985; Rao, 2002). Just as jobs bind workgroups together and workgroups in turn bind organization together, interactions (collaboration and competition ties) bind interdependent organizations in a population (Baum & Amburgey, 2002), bind interdependent populations in a community (Rao, 2002), and more broadly bind interdependent communities in an ecosystem (Autio & Thomas, 2014). The dynamic interactions within each level bind entities together at the next-higher level of the ecological hierarchy (Freeman & Barley, 1990; Greve, 2002). At each level, through interactions, the structure of organization that fittest for the environment is likely to grow and develop. In addition, the heterogeneous nature of a community requires us to consider population as the unit of analysis for describing and explaining the community evolution and dynamics. Community ecology, therefore, is a promising approach complementing population ecology approach which limits its ecological explanation within populations and fails to describe the interactions among populations.

To sum, a comprehensive understanding of community dynamics necessarily requires us to not only explain the variation within different populations which comprise a community, but also describe the interactions among populations within that community. In this regard, population ecology and community ecology approach are complementary. Table 2.4 summarizes the primary differences between population ecology and community ecology.

For nearly four decades, most of the organizational ecology studies focused on ecological dynamics at the population level, and more recently, the evolution of an early IT innovation at the community level (Sun & Wang, 2012). However, the ecological effect on a mature IT innovation such as Customer Relationship Management (CRM) at the community level remains unclear. The theory and associated methods organizational ecologists have developed provide a foundation for moving to higher levels where we can examine the ecology of communities such as those associated with IT innovations.

Table 2.4 Primary Differences in Population Ecology and Community Ecology

	Population Ecology	Community Ecology
Primary argument	1) Competition for limited resources among organizations in a population hinders new entries and opportunity to grow 2) High failure rate and slower growth rate of new entries are caused by limited resources and incumbents in the population	1) Organizations in any one population are fundamentally intertwined with those of organizations in other populations that belong to the same community 2) Inter-organizational relationships among populations of organizations account for the different outcomes of populations
Key concept	Organizational density; Legitimation; Competition	Interaction; Symbiosis (Collaboration); Commensalism (Competition)
Unit of analysis	Organization	Population
Existing limitations	1) Fail to explain origination of organizational forms in an established population 2) Focus on homogeneity interpretation for organization forms selected by environment	1) Ambiguous conceptualization of community composition and coherence 2) Concern on functionality of organizations within community
Sample study and method	Hannan et. al., 1995 Automobile firms Event count analysis	Banett, 1990 US phone industry Event history analysis

Chapter 3: IT Innovations and Communities

This chapter first reviews related work on conceptualizing IT innovation and innovation community. Then, I apply organizational ecology theory to IT innovation community, describe the ecology of IT innovation community, and explain how the dynamic community structure of IT innovation community affects efficient resource use within such community. Finally, I characterize IT innovation community and community structure, and develop the hypotheses.

3.1. IT Innovation

The Merriam-Webster dictionary defines an innovation as “a new idea, device, method, or the act *or* process of introducing new ideas, devices”.⁵ Over decades, scholarly attention has been paid on the study of innovation at both individual level (Rogers, 2003) and organization level (Becker & Whisler, 1967; Daft, 1978) and various definitions of innovation have been given by researchers from different disciplines. For example, Becker and Whisler (1967) defined innovation as "the first or early use of an idea by a set of organizations with similar goals" from an organization perspective, while Rogers (1983), a sociologist, defined innovation as “an idea, practice, or object that is perceived as new and enabled by new technology” from an individual perspective. In strategic management literature, innovation has been viewed as the application of better solutions that meet new requirements, consumers’ needs, or existing market demands (Maranville, 1992), while technology management researchers refer to innovation as something original

⁵ Innovation definition retrieved from: <http://www.merriam-webster.com/dictionary/innovation> (accessed Dec 18, 2015)

and more effective and, as a consequence, new, that "breaks into" the market or society (Frankelius, 2009). These definitions, despite from different fields, all consider innovation, in broad strokes, as something new, original and unexplored, and the process of developing and exploring those things.

IT innovation refers to ideas, practices, or objects associated with a new information technology. Just as ideas are essentially different from physical practices or objects, an IT innovation has least two aspects: conceptual and/or material forms (Swanson & Ramiller, 2004; Wang, 2009). The conceptual elements of an IT innovation refer to a set of ideas that describe the attributes, processes, and possible outcomes of the IT innovation. For example, on one hand, ideas underlying a CRM innovation may include definitions of customer data and methods to capture and analyze the data. On the other hand, the material elements of an IT innovation are the products or objects that exist in the physical world. For instance, the material forms of a CRM innovation may include a CRM software package, a CRM implementation project, resources and processes involved in using CRM, and the customer data going into and coming out of a CRM system. The success and development of IT innovations relies on sustained investment and yet IT innovations are subject to rapid changes, significant uncertainty, and high risk of failure. Because of this complexity, IT innovations are developed iteratively over time through discussions and dialogues that involve many parties which contribute to interpreting the conceptual forms of innovation and transferring them to material innovations (Swanson & Ramiller, 1997; Wang & Ramiller, 2009). Therefore, it is of great importance to understand both the

conceptual and material aspects of an IT innovation in order to capture the process of developing such IT innovation.

The material form of an innovation is often associated with specific organizations such as a lab, where the core technology underlying the innovation was invented, and a company, which commercializes the technology. In contrast, the development, promulgation, and consumption of innovation concepts are not confined within the boundary of any organization, but require the work of many organizations in multiple industries. For example, in the late 1990s researchers at IBM invented the "Loyalty Suite," a business method that integrates CRM operational processes, customer collaboration touchpoints, and CRM analytical processes to identify factors which engender customer loyalty. Granted a patent for this invention, IBM named it "customer relationship management business method" (US Patent #6915270 B1). Despite the patent and its ambitious title, the CRM concept has never been confined to IBM. Others participate in the discourse that develops, spreads, or critiques the concept. Therefore, while developers and adopters directly interact with the materials associated with an IT innovation, they also join others, such as investors, analysts, journalists, consultants, and researchers, in discussing the innovation as a concept in the context of a community (Swanson & Ramiller, 1997). Later, these community ideas are integrated and further shape the development and use of IT innovations. Such collective concept development is undertaken in a community of different organizations interested in the innovation.

3.2. Innovation Community

Just as innovation has attracted many scholarly attentions from different fields, the idea of an innovation community exists in many disciplines as well. In institutional theory literature, DiMaggio and Powell (1983) suggested the concept of an "organizational field" to encompass organizations that, in the aggregate, comprise of suppliers, resource and product consumers, regulatory agencies, and other related organizations. Writing about technology & innovation management, Lynn et al. (1996) proposed "innovation community" as a term to refer to the organizations directly and indirectly involved in the commercialization of a new technology. In social theory and research, actor network theory considers that all actors and intermediaries with their relationships comprise a network, and they work together to enact such network (Callon, 1990; Latour, 2005). Organizational ecologists referred a set of functionally integrated and interdependent organizations as an "organizational community" (Astley & Fombrun, 1987; Brittain & Wholey, 1988). In the later work, Freeman and Barley (1990) further developed the concept of an organizational community arguing that community members in this framework involved different populations including but not limit to technology firms, universities, research institutes, established corporations, industrial associations, scientific bodies, and suppliers. Recent technology & innovation management literature has conceptualized "idea innovation networks" consisting of six functional arenas (basic research, applied research, product development, production research, quality control, and commercialization), where various organizations engage in the production of innovations (Hage & Hollingsworth, 2000). Overall, the literatures from a wide array

of disciplines suggest that the idea of an innovation community has expanded beyond production of innovations by research and development (R&D) organizations to all parties, being involved in producing innovations. Therefore, drawing different views on innovation community from institutional theory, technology& innovation management, network theory, and organizational ecology theory, innovation community in this dissertation is defined as a community consisting of a variety of populations of organizations, united in their focus on producing and/or using an innovation, but differentiated by the interests related to the innovation and the roles they play in the community (Hage & Hollingsworth, 2000; Sun & Wang, 2012; Swanson & Ramiller, 1997; Wang & Ramiller, 2009).

In innovating with a new technology, an innovation community with a variety of community members emerges to make sense of the innovation and orchestrate material activities related to the innovation (Swanson & Ramiller, 1997; Wang & Ramiller, 2009). From the production of innovation perspective, innovations are supplied by not only populations of R&D organizations, but also populations of design companies, venture capital firms, advertising agencies, wholesalers, and retailers, whose activities are regulated by industrial or professional organizations and/or the government. In addition, as Edgerton (2007) argued, if an innovation is abandoned or not adopted by organizations given the ineffective innovation diffusion, the social and economic value of such innovation will not be realized. From the diffusion of innovation perspective (Rogers, 2003), innovating with IT in organizations, is a journey that involves four core processes: comprehension, adoption, implementation, and assimilation (Swanson & Ramiller, 2004). First, basic

ideas (e.g., existence and attributes) about the innovation are collected by organizations from their environments (e.g., community) and organizations consume the information from various channels (e.g., news media) for comprehending the innovation. Then, the degree of comprehension of the innovation helps organizations to decide whether or not to adopt the innovation, with the articulation of supporting and opposing rationales provided by industry researchers. In the third stage, organizations adopt the innovation, which involves installing the hardware and software, and meanwhile business processes are changed with the help of consultants, and so on. Finally, the innovation becomes assimilated into the routines of organizational work systems and universities may start to research the development of the institutionalized innovation. Therefore, each adopter's (e.g., organization) innovation journey is supported and affected by including but not limiting to populations of consultants, industry research firms, news media, universities, and financial institutions.

Overall, an organization is not alone in its struggle to make sense of an innovation. Rather, an inter-organizational community comprising of different populations of organizations come together, both informally and formally, to engage the material and discursive aspects of producing and using innovations (Swanson & Ramiller, 1997; Wang & Ramiller, 2009). Members in an innovation community play different roles, paying close attention to the innovation, and discuss publicly what the innovation it means and how it is going. For example, technology providers and consulting firms provide assistance in planning, selection, and implementation for their products and related services. Their offerings are associated with new concepts

and ideas that later are integrated into the innovation community (Swanson & Ramiller, 1997). Journalists in the innovation community usually spread, interpret, and suggest additional information about the innovation, the use of innovation, and its possible future. Academic and industry researchers add their voices to the innovation community as well. For academic researchers, they seek to instill their distinctive work in the community, while industry researchers seek to cooperate with companies to make better use of the innovation. All in all, in an innovation community, community members surrounding the technology provider devote their efforts to making sense of the innovation and transferring it from vision to actuality. Technology providers, consultants, journalists, and academics sell their “products” with their own ways in an innovation community, where many new and innovative ideas are potentially adopted by organizations (Swanson & Ramiller, 1997). Thus, the nature of an innovation community suggests that the innovation community is often highly active and subject to changing in the context of public discussions (Abrahamson, 1991). Participants (populations) in the innovation community evolves dynamically, as the collective attention to the innovation evolves (Swanson & Ramiller, 1997), and eventually leads to the dynamic community evolution (Baum & Rao, 2001; Greve, 2002; Hannan & Carroll, 1992). In this dynamic process, the activities of community participants and their associated interactions play a significant role in shaping the community dynamics (Freeman & Barley, 1990; Rao, 2002; Van de Ven & Garud, 1993). Meanwhile, these interactions and activities provide important information to the participants in the community and help them build the "cognitive networks" (DiMaggio, 1992) and establish inter-organizational

relationships on which community participants must rely when translating an innovation from vision to actuality.

3.3. Ecology of An Innovation Community

As detailed in the prior section, an innovation community is a heterogeneous inter-organizational community that encompasses diverse populations of organizations with different interests related to an innovation. An innovation community contains different inter-organizational relationships, through which populations of organizations interact with each other. The most two prevalent inter-organizational relationships are collaboration and competition (Baum & Rao, 2001; Rao, 2002), which are embedded within and among populations of organizations in an innovation community. As community ecology posits, inter-organizational relationships such as collaboration and competition allow communities to become functionally integrated systems, in which different populations interact and exchange resources more with each other than directly with the environment (Astley, 1985). As a result, populations in an innovation community become fundamentally interdependent. When an innovation emerges, these different populations work together to negotiate the content of the innovation and make sense of the innovation in the innovation community (Swanson & Ramiller, 1997). Therefore, if we are to fully understand the outcome and development of an innovation, we first need to understand the ecology of an innovation community and explain how different populations of organizations that compose the innovation community evolve dynamically.

Table 3.1 describes some roles that organizations play in the CRM innovation community, including academic researcher, adopter, consultant, industry researcher, and technology provider.

Table 3.1 Diverse Roles Organizations Play in the CRM Innovation Community from Computerworld

Role	Sample Organization	Sample Sentence from CRM Articles in <i>Computerworld</i>
Academic Researcher	Temple University	SAP AG's U.S. subsidiary is teaming up with two Temple University professors to develop a benchmarking tool that's designed to help chemical companies assess their customer relationship management (CRM) capabilities. (08/12/2002)
Adopter	Barnes & Noble	As vice president of planning and analysis and new business at Barnes & Noble Inc. in New York, he is using E.piphany's E.5 CRM package to manage and track direct-mail responses and customers' e-mail requests. (06/11/2001)
Consultant	Andersen Consulting and KPMG Peat Marwick	The technology includes computer-telephony integration and interactive voice-response products, call-center and sales force automation technologies as well as middleware and services for integrating and analyzing information gathered from customers. Major companies in this space include IBM, NCR Corp., Unisys Corp. and consulting firms such as Andersen Consulting LLP and KPMG Peat Marwick LLP. (08/17/1998)
Industry Researcher	Forrester Research	In the heavy-truck industry, what's needed is to have a continual view of the status of a vehicle and to provide service to customers on the road," said Steve Cole, an analyst at Forrester Research Inc. in Cambridge, Mass. (11/22/1999)
Technology provider	Siebel Systems	Mentor Graphics, which uses Sales Enterprise from San Mateo, Calif.-based Siebel Systems Inc., is part of a growing trend in sales force automation: companies switching from focusing on process automation to improving the customer's experience. (08/16/1999)

The community roles that different organizations play allow them to form various inter-organizational relationships and make them interdependent. Van de Ven and Garud (1993) suggested that an innovation idea/concept could be transferred to a material innovation through activities of community members. The activities resulting in the co-development of conceptual and material aspects of an innovation can be understood from supply and demand perspective. From supply side, technology providers play a critical role in planning, selecting, and implementing an innovation

and providing related services. Their offerings are often associated with new concepts and ideas that later are integrated into the community (Swanson & Ramiller, 1997). From demand side, innovations must be adopted or in demand so that their social and economic value can be realized (Edgerton, 2007). In this regard, adopters have the power to make a decision about the selection of their “ideal products and services” from technology providers. Their decisions and feedback are the motivation for competition among technology providers and encourage technology providers to transfer new innovation concepts and ideas to material innovations for being more competitive in the market (Frambach et al., 1998; Lyytinen & King, 2006; Weigelt & Sarkar, 2009).

In addition, one population in a community is not only affected by the feedback processes from other populations, but more importantly by the direct interactions with other populations (Hannan & Freeman, 1993). Within an innovation community, the reciprocal interaction between the supply side (technology providers) and the demand side (adopters) and their engagement further help to make sense of an innovation (Waarts et al., 2002). As Swanson and Ramiller (1997) argued, the adoption of an IT innovation was supported by a functioning inter-organizational community which welcomes the engagement of all community members and their discussion on the focal community ideas. When populations of organizations participate in developing and spreading the concept of an innovation, they contribute to interpreting the innovation. This argument was further confirmed by Wang and Ramiller (2009) with a qualitative study examining the roles and activities that each community member plays. Besides the outcomes of reciprocal collective learning

among community members, Wang and Ramiller (2009) found that two community members play a significant role when developing the concepts or knowledge associated with an innovation. In particular, technology providers take leadership early-on in interpreting the innovation with rationales (“know-what” and “know-why”) and later on adopters come to dominate the innovation community as its focus shifted to the capabilities of how to use the innovation with strategies (“know-how”).

When an innovation emerges in an innovation community, diverse populations of organizations join in the innovation community and stay to play their roles to shape the development and outcome of the innovation over time (Sun & Wang, 2012; Swanson & Ramiller, 1997; Wang & Ramiller, 2009). For example, technology providers and adopters take the lead to engage in and co-develop the conceptual and material aspects of an innovation in an innovation community (Hargrave & Van De Ven, 2006). Later, other community members join in the innovation community motivated by the interpretation of the innovation from technology providers and rational adoption from adopter, and begin to learn from each other about the innovation. Inspired by the participation of technology providers and adopters, the reciprocal collective learning processes finally result in each community member’s comprehensive understanding of the innovation. The innovation community evolves, as its community members develop and grow (Greve, 2002; Wang & Ramiller, 2009). Thus, an innovation community necessarily needs a sufficient number of technology providers and adopters participating to become viable and function effectively (Baum & Amburgey, 2002; Baum & Rao, 2001; Rao, 2002).

An innovation community is a heterogeneous inter-organizational community that incorporates diverse populations of organizations with different interests related to an innovation. Populations in an innovation community are differentiated, in part, by their different interests and by the different roles they play in an innovation community (Swanson & Ramiller, 1997; Wang & Ramiller, 2009). Therefore, organizations playing the role of technology provider can be thought of as a distinct population that seeks to provide the technology or related services in an innovation community. Similarly, organizations playing the role of adopter can be considered as a distinct population that adopts the technology from technology providers.

As reviewed in Section 2.4 and 2.5, a comprehensive understanding of community dynamics needs that we first describe how populations of organizations playing different roles develop. However, traditional community ecology studies have usually treated each community as a whole and explained community dynamics by examining the entry of all organizations in the aggregate (See Table 2.3) without separately considering the participation of each population and their distinct contributions to the community. Recent community ecology work has acknowledged this limitation and described populations of organizations playing different roles in an innovation community (Sun & Wang, 2012). However, this study has not empirically examined the heterogeneous nature of an innovation community and taken into account how distinct populations (e.g., technology providers and adopters) in the innovation community develop.

In an innovation community, technology providers offer new technologies, integrate innovative ideas/concepts, and make incremental improvements on existing

technologies in order to being more competitive in an innovation community (Chrisman et al., 1998; Lyytinen & King, 2006; Shepherd & Zacharakis, 2003). In contrast, adopters work with other community members to comprehend the new technologies, make their decisions on the selection of the new technologies from technology providers, and provide useful feedback regarding their use of the new technologies. The participation of technology providers and adopters contributes to making a connection between supply side and demand side, as their associated interaction allows technology providers and adopters to negotiate and co-develop the conceptual and material aspects of the innovation (Hargrave & Van De Ven, 2006; Swanson & Ramiller, 1997; Van de Ven & Garud, 1993). Further, collective learning among community members inspired by the participation of technology providers and adopters advances each community member's understanding (e.g., "know-what", "know-why", and "know-how") of the innovations (Wang & Ramiller, 2009). Overall, the participation of both technology providers and adopters is necessary if an innovation community is to be viable and evolve dynamically. In this regard, a thorough description of how population of technology provider and adopter involved in an innovation community develop is an important part of unpacking the innovation community dynamics.

In population ecology, the variation within a population signals the development of the population (Rao & Singh, 1999). Variation within a population manifests in two vital rates: the entry rate, or the rate at which new organizations enter or are founded in the population; and exit rate, or the rate at which existing organizations fail or leave the population. Variation occurs when organizations enter

or exit from a population. Organizational entry rate is primarily used to measure and explain the growth of a population over a long time period (Hannan et al., 1995; Hannan & Freeman, 1977). On the contrary, organizational exit rate is considered when we want to understand why incumbents declined and disappear in a population over a long time period (Agarwal et al., 2002; Baum & Singh, 1994; Freeman et al., 1983; Zaheer & Mosakowski, 1997). Since this dissertation mainly seeks to answer the research question: *how does the composition within an IT innovation community shapes its subsequent growth and development*, I focus on organizational entry rate which explains the growth of populations that compose an innovation community.

As Hannan and Freeman (1993) suggested, the organizational entry rate in a population is affected by the number of organizations in that population. The number of organizations in a population is restricted by two ecological processes: legitimation and competition. Legitimation refers to the process of making something acceptable and normative to a group or audience within a given society (Zucker, 1989). Legitimation is the act of providing legitimacy and in population ecology legitimation confers legitimacy on organizations within a population (Hannan et al., 2007). Organizations need to establish and maintain their legitimacy in order to stay in a population. Legitimacy is an assumption that the actions of an entity are proper or appropriate within some socially constructed system of norms (Suchman, 1995). Organizations in a population must conform to institutionalized norms to maintain their legitimacy for survival (Hannan & Freeman, 1977; Meyer & Rowan, 1977; Zucker, 1989).

As population ecology posits, increasing legitimacy of a population attracts new organizations to that population and reduces the exit rate of incumbents. This is because new organizations usually face the challenge of lacking legitimacy when they are trying to enter a population. For new organizations, establishing legitimacy is very uncertain and highly time consuming process that demands significant efforts. In this regard, new organizations usually follow the industry standard created by existing organizations to avoid high risk and uncertainty and maintain legitimacy in the population (Meyer & Rowan, 1977; Zimmerman & Zeitz, 2002). As a result, the legitimacy of a population increases, as more and more organizations enter the population, which in turn, attract even more new organizations.

Meanwhile, organizations compete with each other for limited resources and the increasing competition will hinder new organizations from entering the population. This is because similar types of organizations compete for limited resources in a population. For existing organizations, the competition is already there within a population and they have to compete with each other for survival. For new organizations, they have to assume the risk of entering a population without being legitimated (Hannan & Freeman, 1977; Zucker, 1989), but even more they have to compete with incumbents for limited resources. As a result, organizations are reluctant to enter a population, as the competition increases in that population. Overall, legitimation and competition constrains the number of organizations in a population and the number of organizations affects the organizational entry rare in the population.

Therefore, if we are to understand the variation within a population in terms of organizational entry rate, we need to measure the legitimation and competition in the population. In population ecology research, the density-dependence model is illuminating because it rigorously models legitimation and competition which effectively explain the relationship between the number of organizations in a population and the organizational entry rate. In density-dependence model, both legitimation and competition are driven by density, the number of organizations in a population, and hence the name “density-dependence” (Hannan et al., 1995). The density-dependence model assumes that legitimation increases organizational entry rates, while competition has the opposite effects. Legitimation is measured by organizational density and competition is measured by the quadric term of density.

In population ecology, legitimation is one factor that affects organizational entry rate in a population. In an innovation community, legitimation affects the organizational entry of technology provider. New technology ventures usually face the challenges of lacking of legitimacy when developing new technologies in their early stage. This is because the actions they take are lack of wide acceptance within a socially constructed system of norms (Suchman, 1995). Yet, building-up of legitimacy is a very uncertain and highly cost process that demands significant efforts from new ventures (Zimmerman & Zeitz, 2002; Zucker, 1989). Legitimation in technology provider population suggests that norms of technologies, related rules and industry standard that existing organizations established have been well recognized and accepted within the population (Shepherd & Zacharakis, 2003). Since legitimation confers legitimacy on organizations within a population, new

organizations that enter the technology provider population will suffer less risk of failure and devote less efforts to maintain legitimacy if they follow those well-developed standards in that population. As new organizations join in the technology provider population and stay to play their roles, the legitimacy of the population increases. The increasing legitimacy of technology provider population, as a result, attracts more organizations to the population and reduces the failure rate of incumbents. Therefore, the behaviors of the new entrants in technology provider population suggest:

Hypothesis 1: the entry rate of organizations that play the role of technology provider is positively associated with legitimacy in an IT innovation community.

Yet, beyond the legitimation effect on the organizational entry rate, competition is also in evidence. This ecology effect can be found within populations, sometimes more severe (Tang et al., 2014) in the context of an innovation community. Within the technology provider population, competition arises directly from the need of similar organizations for resources. Organizations playing the role of technology provider compete for resources such as development partners, implementers, media coverage, and, ultimately, adopters. On one hand, for the organizations already in the population, they face the chance of exiting given the existing competitions among themselves. Incumbents have to compete with each other for these limited resources in the pool for their survival. On the other hand, new technology ventures face the challenges of taking advantage of these limited resources that incumbents have already competed for and competing with incumbents who have already established competitive advantages in the population (Chrisman et

al., 1998; Lyytinen & King, 2006; Shepherd & Zacharakis, 2003; Zimmerman & Zeitz, 2002). As a result, new technology ventures are reluctant to enter the population due to the uncertainty of available resources and significant efforts of competing with incumbents. Therefore, as more and more organizations playing the role of technology provider stay in the population, the increasing competition for resources will deter new organizations from entering the population. Hence,

Hypothesis 2: the entry rate of organizations that play the role of technology provider is negatively associated with competition in an IT innovation community.

As detailed before, an innovation community necessarily needs both the participation of technology provider (supply side) and adopter (demand) to function and develop well. Just as legitimation and competition constrain the number of organizations in the population of technology provider and hence affect the organizational entry rate, the number of organizations in the population of adopter is restricted by legitimation and competition as well.

Legitimation in adopter population suggests that the values, benefits, features and functions of the technologies have been well identified by incumbents, and they make decisions on the selection of technologies which fit them best. For those new organizations, they are more likely to conform to institutionalized norms that incumbents made, follow their steps and choose the “right” technologies to maintain their legitimacy in the population (Meyer & Rowan, 1977). As new organizations join in the adopter population and stay to play their roles, the legitimacy of the adopter population increases. The increasing legitimacy of the adopter population, as a result, attracts more organizations to the population given the cost/benefit (e.g., less effort

for maintaining legitimacy) of adopting the technologies. Therefore, the behaviors of the new entrants in adopter population suggest:

Hypothesis 3: the entry rate of organizations that play the role of adopter is positively associated with legitimation in an IT innovation community.

Similar as technology providers compete for resources for survival, adopters compete as well. Organizations playing the role of adopter compete for resources such as time and knowledge of experts and consultants and attentions & services from technology providers. On one hand, for the organizations already in the population, they face the possibility of having difficulties in understanding and adopting the technologies given less assistance from consultants and attentions & services from technology providers. Existing adopters have to compete with each other for these limited resources so that they can better adopt the technologies and make profits in their own business domains. On the other hand, new adopters have difficulties in making use of these limited resources that incumbents have already competed for. As a result, new adopters are averse to enter the population due to the uncertainty of available resources and significant efforts of competing with incumbents. Therefore, as more and more adopters stay in the population, the increasing competition for resources will deter new organizations from entering the population. Hence,

Hypothesis 4: the entry rate of organizations that play the role of adopter is negatively associated with competition in an IT innovation community.

Together with these hypotheses describing the variation within population of technology provider and population of adopter, the ecology theory of innovation community aims to address the question " *how does the composition within an IT*

innovation community shape its subsequent growth and development " in two ways.

First, the theory extends from prior studies of innovation outcomes at the organizational and population levels, considering factors and actors in a much broader “niche”. Second, the theory has the potential to unpack the innovation community dynamics discovered in prior research and shed light on the how populations of organizations playing specific community roles in part shape the innovation community dynamics.

This section reviews the ecology of an innovation community, explain how the dynamics of community is in part affected by ecological forces (legitimation and competition) within populations that compose the community, and correspondingly raise related hypotheses at the community level. Yet, it is not clear that how vivid community structure which involves different inter-organizational relationships shape the dynamics of an innovation community. The next section will explore the related network theory and applies it to study the structure of innovation community.

3.4. Structure of an Innovation Community

3.4.1. Dynamic structure of an innovation community

In the IT innovation world, it is common for two IT innovation communities have similar sizes during early years, but for one innovation to become the "next big thing," while the other just quietly disappears. Their different destinies suggest that the number of organizations & organizational density, which affects the entry rate of organizations in each population, may not be sufficient to fully explain the dynamic changes, as an innovation community evolves. In addition, the measures of legitimation and competition based on organizational density in the density-dependence model are unlikely to capture various activities that populations take to innovate within an innovation community (Freeman & Barley, 1990; Hannan et al., 1995; Singh et al., 1993). Yet, the activities that populations take within an innovation community not only allow them to co-develop the conceptual and material aspects of an innovation (Hargrave & Van De Ven, 2006; Swanson & Ramiller, 1997; Van de Ven & Garud, 1993), but also let populations form different inter-organizational relationships (Table 3.2) which shape the innovation community dynamics overtime (Baum & Rao, 2001; Greve, 2002; Rao, 2002).

Table 3.2 Types of Relationships between Organizations Co-Mentioned in the Same Paragraph from Computerworld

Relation	Organizations	Sample Sentence from CRM Articles in <i>Computerworld</i>
Adoption	SAP AG and Osram Sylvania	Osram Sylvania Inc., a lighting manufacturer in Danvers, Mass., this spring plans to be one of the first users to install pieces of SAPAG's new customer relationship management (CRM) software. (03/27/2000)
Collaboration	SAP AG and Commerce One	Enterprise resource planning giant SAP AG already publishes many application program interfaces in XML and is working with Commerce One Inc. in Pleasanton, Calif., on a common business library for external transactions. (04/22/2002)
Competition	Youcentric and Siebel Systems	Analysts say Youcentric Inc is a small player in the CRM market, which is dominated by Santa Clara, Calif.-based Siebel Systems Inc. (05/15/2000)
Merger, Acquisition, & Divestiture (MA&D)	Siebel Systems and Janna Systems	January, Siebel said it would extend the buying spree by purchasing Toronto-based Janna in a stock swap valued at \$975 million, based on the Sept. 11 closing price for Siebel's shares. The acquisition of Janna -- which had sales of \$13 million last year and \$12.6 million during the first half of this year -- is expected to be completed in the fourth quarter. (09/18/2000)
Research	Salesforce.com and Forrester Research	Strong integration tools are necessary as Salesforce.com continues to try to move "upmarket" into larger deployments, said Forrester Research Inc. analyst Liz Herbert. (11/30/2006)

As detailed in Section 2.4, community dynamics are arose by population variations when new organizational forms are created by entrepreneurs within communities. In the selection of populations within a community, inter-organizational relationships (e.g., collaboration and competition) affect community dynamics when populations interact with each other (Baum & Rao, 2001). Astley (1985) argued that inter-organizational relationships such as collaboration and competition make communities become functionally integrated systems with structures, in which

populations interact and exchange resources more with each other than directly with the environment. These inter-organizational relationships make populations that play different roles (Table 3.1) in a community more interdependent and enact a network within the community that shapes a hierarchical structure in the community over time (Freeman & Barley, 1990; Greve, 2002; Gulati & Gargiulo, 1999; Rao, 2002).

Therefore, when a population interacts with other populations within a community, it is necessary to consider its relationship with those other populations. Inter-organizational relationship that shapes the community structure is, therefore, another important aspect for understanding community dynamics.

3.4.2. Resource distribution and use in an innovation community

Communities of the same size may have very different structures composed of different populations that are connected through different types of inter-organizational relationships. In organizational ecology, similar organizations have to compete with each other for limited resources and hence constrain the number of organizations in a population. However, as posited in niche width theory and resource partitioning theory, if organizations within a population can better take advantage of the resources (i.e., similar organizations are able to capture resources differently or use different resources), additional available resources left in the pool can support and provide opportunities for new entries (Carroll & Swaminathan, 2000; Freeman & Hannan, 1983; Hannan & Freeman, 1977). On one hand, in niche width theory, Freeman and Hannan (1983) argued that the survival of organizations was subject to the available resources in a population, the distribution of resources, and how organizations use them. Resources in a population include but are not limited to

public attention, government/private support, technical employees, expertized consultants, and ultimately, potential customers. Such resources come from the environments where organizations reside and different resources are available in different contexts (Amburgey & Rao, 1996; Hannan & Freeman, 1993).

Organizations with structures that most fit the environment are likely to survive because of their capability to better take advantage of the available resources. The niche width theory suggested that some types of organizations were able to make better use of resources distributed in the population and thus were more likely to survive.

On the other hand, based on niche width theory, resource partitioning theory further explains how organizations were able to better use resources, and/or capture resources differently. For example, Carroll and Swaminathan (2000) suggested that organizations in a population could coexist on the same resources if each organization uses different resources, or is able to capture resources differently. Different types of organizations (e.g., general form and special form) in a population can coexist when organizations are limited by different resources such as technical employees, expert, consultants, and potential customers. For example, large firms have a broader niche and consume a wide range of available resources, while small firms have a narrower niche and take advantage of the resources to a greater degree. Large firms tend to recruit more experienced employees and work with famous consultants in order to attract and maintain relative number of customers in the population. Small firms, in contrast, are more likely to recruit novice employees and work in their space in order to survive and grow in the population. Overall, different strategies of exploiting

resources help organizations coexist by allowing those organizations to utilize different resources, and/or access resources differently (Carroll & Swaminathan, 2000; Freeman & Hannan, 1983).

Specifically, with regard to different ways of resource use by organizations seeking to join a population, one typical strategy is imitation (Ceccagnoli, 2005; Ruckman et al., 2015; Zimmerman & Zeitz, 2002). When new organizations want to join a population, they often imitate incumbents' ways of exploiting resources to reduce the risk of failure and allow them to devote less effort to maintaining legitimacy (Meyer & Rowan, 1977). As new organizations join a population and start to imitate incumbents (Ruckman et al., 2015), the legitimacy of that population increases. The increasing legitimacy, as a result, attracts more organizations to the population. Even though this imitation can result in more direct competition, the reduced effort of learning how to efficiently use resources and increased legitimacy allows more entrants (Hannan & Freeman, 1993; Zucker, 1989).

Second and more importantly, utilization of different resources by organizations provide new opportunities to entrants and attract them to join a population. Research on entrepreneurship (Shane, 2001; Thornton, 1999) has suggested that new business opportunities tend to attract entrants. In particular, new entrants are more likely to join a population when technical, commercial, and information resources become accessible, which, as Freeman (1983) suggested, is primarily achieved through the utilization and distribution of different resources by organizations in that population. The utilization of different resources leads to the co-existence of organizations in the population. In addition, drawing on the niche width

theory, resource partitioning theory suggests that accessing resources differently by organizations strengthens their ability to join a population (Carroll & Swaminathan, 2000). For organizations seeking to join a population, they usually face high uncertainty and the challenge of exploiting resources that incumbents already compete for, and thus favor to avoid direct competition with incumbents (Ceccagnoli, 2005; Cohen & Klepper, 1992; Fleming, 2001). Instead, those new organizations tend to capture the resources that are different from those resources used by incumbents, and grow in their own space (Cooper & Folta, 2000). In sum, resource use strategies allow new organizations to imitate incumbents and correspondingly attract new organizations to enter a population. Second, utilization and distribution of different resources provide opportunities to new organizations for joining the population. Last but not least, organizations' ability to capture resources differently further increases their possibility to enter the population.

Within a population, organizations wisely using available resources encourage new entries in that population. Resource use strategies occur within an innovation community as well. Similar to competition among organizations in population ecology (Hannan & Freeman, 1977), populations in innovation communities have to compete with each other for resources to grow. Resources in an innovation community include but are not limited to public attention, innovative ideas, media coverage, information about the use of innovation, information about the technology involved in the community, support from government, and ultimately, audiences.

However, as community ecologists argued (Astley, 1985; Rao, 2002), populations can coexist when each population uses different resources, or are able to

capture resources differently. First, within an innovation community, populations consume and use different resources based on the different roles they play in that community. For example, resources (e.g., attention and media coverage) that technology providers consume are different from those resources that adopters in an innovation community consume, as different populations focus on different audiences and targets. Therefore, different populations in an innovation community are less likely to fiercely compete with each other for the same resources. On the contrary, populations establish various inter-organizational relationships with each other for mutual benefit (Astley, 1985; Baum & Amburgey, 2002; Baum & Rao, 2001; Greve, 2002; Rao, 2002).

In an innovation community, organizations undertake various activities to make sense of an innovation and are connected by different inter-organizational relationships through these activities (Baum & Rao, 2001; Hargrave & Van De Ven, 2006; Swanson & Ramiller, 1997; Van de Ven & Garud, 1993). These inter-organizational relationships within and among populations of organizations make them interdependent and form an inter-organizational network within an innovation community (Gulati & Gargiulo, 1999). As detailed in the previous section, an innovation community necessarily needs the participation of technology providers and adopters to develop well. Technology providers play the role of making and establishing connections with different community members. For example, the interaction between technology providers and adopters encourages reciprocal collective learning among community members to further comprehend the technology, which in turn, results in useful feedback to technology providers and

allow them to make sustained improvements to the technology. Such collective learning processes allow technology providers to form and maintain *adoption* relationship with adopters, *competition/collaboration* relationships with other technology providers, *research* relationships with industry/academic researchers (Sun & Wang, 2012; Wang & Ramiller, 2009). Adopters, in contrast, play the role of consuming and spreading information about the technology, and their *collaboration* with consultants usually help an innovation community better understand the technology. Overall, all these interactions within and among populations are established through the inter-organizational network in the innovation community.

Second and more importantly, each population's access to different resources and the ability to capture resources differently are supported and reinforced, thanks to the inter-organizational network in which it is embedded. For example, within an inter-organizational network, different technology providers can be connected with different partners, making them different from one to another, and establish different strategic relationships (e.g., adoption) with organizations from other populations in an innovation community (Gulati & Gargiulo, 1999; Gulati et al., 2000). Therefore, new technology providers seeking to avoid direct competition with existing technology providers for resources (e.g., customers and partners) will be less likely to build connections with the same customers and partners that have already established strategic relationships with existing technology providers (Lavie, 2007). Instead, new technology providers are more prone to exploit other available resources which are not currently used by existing technology providers, develop, and grow in their own space so that they can avoid direct competition, higher uncertainty and risk of failure

within the innovation community (Ceccagnoli, 2005; Cohen & Klepper, 1992; Fleming, 2001; Freeman & Hannan, 1983; Gulati et al., 2000; Lavie, 2007). Similarly, adopters with different networks do not have to compete with each other for the same resources either, given the inter-organizational relationships with organizations from other populations. For instance, rather than adopting the same technology and competing for attention from the same technology provider and consultants, adopters in an innovation community can choose to work with different technology providers. Such strategic decisions by adopters primarily come from their reluctance to dedicate so much effort to competing with other adopters for resources with high uncertainty (Ceccagnoli, 2005; Cohen & Klepper, 1992; Freeman & Hannan, 1983; Lavie, 2007).

Overall, distinct resource use and access of different resources by organizations at the community level are dependent on inter-organizational relationships within and among populations (Freeman & Barley, 1990; Rao, 2002). These inter-organizational relationships enact a network structure within an innovation community and function as a resource infrastructure which allows different organizations to access different resources and strengthens their abilities to capture resources differently. For new entrants, if they are able capture resources that are different from those used by incumbents, organizations are more likely to enter the innovation community, as their access to different resources are supported by the inter-organizational network, and their concerns on competition with incumbents for resources are mitigated (Cooper & Folta, 2000; Fleming, 2001; Lavie & Rosenkopf, 2006).

Last but not least, in addition to allowing different organizations to access diverse resources and strengthening their ability to capture different resources (Carroll & Swaminathan, 2000; Freeman & Hannan, 1983), the inter-organizational network also functions as an infrastructure which facilitate efficient information diffusion and communication within and among populations (Barabási & Albert, 1999; Li et al., 2005). A good and convenient conduit of information transmission and diffusion is of great value for both incumbents and entrants within an innovation community (Feldman, 2001; Fleming, 2001). For incumbents, knowing when and where to find what resources (e.g., skilled employees) requires them to closely track the information spread within the dynamic the inter-organizational network, as the broader community usually offers more resources than the industry analysts report. For new entrants, as detailed before, they are more likely to join the community for fostering the innovation when they are able to utilize the diverse inter-organizational resources that are not taken advantage by incumbents (Ceccagnoli, 2005; Cohen & Klepper, 1992; Glaeser et al., 1992). Knowing when and whether to join an innovation community also requires new entrants to closely track the information spread within dynamic the inter-organizational network. Hence, an inter-organizational network structure should facilitate the exploitation of resources and information by new entrants and attract them enter an innovation community.

In sum, populations in an innovation community use different resources based on the different roles they play. But more importantly, inter-organizational network strengthens each population's ability to capture different resources. When organizations are able to capture resources that are different from those used by

incumbents, they are more likely to join a population. Third, an inter-organizational network helps new entrants to make strategic decisions on whether and when to join a population by providing valuable information within it. In other words, different populations are more or less able to use the available resources effectively based on the inter-organizational network in which they are embedded in. Overall, a population with a network structure that can utilize diverse inter-organizational resources is able to accommodate more organizations in that population, which, in turn, supports more entries in an innovation community. But, how to characterize the efficiency of a network structure that results in more entries in an innovation community? The next sub-section about scale-free network will reveal the puzzle.

3.4.3. Scale-free network

Comparing populations (and ultimately innovation communities), network requires measures that capture the network ability to support efficient resource use. Regarding the measure of a network structure that can utilize resources efficiently, prior work has suggested that scale-free is a good candidate, because scale-free considers the function of highly-connected nodes in a network and characterize the efficient of a network to reinforce information transmission and diffusion (Li et al., 2005; Sun & Wang, 2012).

The term “scale-free” network was first coined by Barabási and Albert (1999) to describe the type of network that has a “heavy-tailed effect” following a pareto distribution or power law distribution. The “heavy-tailed effect” was first found in the biological and social networks (Barabási & Albert, 1999). A scale-free network has nodes that are connected not randomly or evenly, but includes a few highly-connected nodes to connect other nodes in the network (Barabási, 2003).

In a scale-free network, the highly-connected nodes refer to the nodes that have higher degrees (i.e. more connections) than other nodes. Highly-connected nodes are not in the presence as many as other nodes in a scale-free network. Therefore, the distribution of node degree follows a power law in which most nodes have only a few connections and some nodes have a large number of connections.

The most notable characteristic of a scale-free network is the highly-connected nodes and their functionality. The highly-connected nodes⁶ are also called "hubs" (Callaway et al., 2000; Cohen et al., 2000, 2001) and function as “bridges” to

⁶ Highly-connected nodes are also refereed as the hubs of the network in Cohen et al. (2000, 2001) and Callaway et al. (2000).

connect with other peripheral nodes in the network. In a scale-free network, the majority of the highly-connected nodes are closely followed by the smaller ones, which in turn, are followed by other nodes with even few connections and so on. This hierarchical network structure allows for efficient information diffusion thanks to the functionality of highly-connected nodes and ensures efficient and stable communications among nodes (Barabási, 2003), which results in the efficiency of a network (Barabási & Albert, 1999). For example, if information diffuses within and between those nodes with few connections, it usually takes a long time for the majority of the nodes in the network to receive such information. On the contrary, if information transmission goes through highly-connected nodes with many connections, it takes less time for the majority of the nodes in the network to receive such information. This is because highly-connected nodes function as “bridges” to establish connections between core nodes and peripheral nodes, make the network structure smoother and more efficient, and allow for fast information diffusion by shortening the “distance” between nodes in the network (Callaway et al., 2000; Cohen et al., 2000, 2001). Thus, highly-connected nodes are of great importance in a scale-free network. The more highly-connected nodes are present in a scale-free network, the more efficiently information can be spread in that network, and hence the more scale-free and/or efficient a network will be. Indeed, Cohen et al. (2000; 2001) and Callaway et al. (2000) have analyzed and confirmed the functionality of highly-connected nodes. Li et al. (2005) has suggested that highly-connected nodes are very efficient in spreading information in the network.

The highly-connected nodes can also be seen in an innovation community. In an innovation community, populations of organizations engage in various activities to make sense of an innovation and are connected by different inter-organizational relationships arising from these activities (Hargrave & Van De Ven, 2006; Swanson & Ramiller, 1997; Van de Ven & Garud, 1993). The inter-organizational relationships within and among populations of organizations make them interdependent and form a network in an innovation community. As detailed in Section 3.3, an innovation community necessarily needs the early participation of technology providers to function well. To sell their products and provide related services, technology providers are usually highly-connected with organizations playing other roles and establish various relationships (Table 3.2) in an innovation community. Further, as is suggested by Hannan (1984), a community can be built around a particular technology which accommodates various skilled and knowledgeable organizations around that technology. Hence, not only the participation of technology providers reflects their central role in the network, but also the nature of community suggests technology providers are hubs in an innovation community. Last, as hubs in an innovation community, technology providers interpret the innovation and provide rationales (“know-what” and “know-why”) to other community members in an innovation’s early stage, they also function as information brokers, through which other community members can form relationships with each other. For instance, adopters usually form *collaboration* relationships with consultants to seek advice from so that they can better understand and adopt the technology.

To conclude, technology providers play a central role and function as highly-connected nodes, and meanwhile they help to establish various relationships with other community members in an innovation community. Within an innovation community, technology providers play an important role of distributing resources such as the relevance of an innovation, the use of an innovation, and the development of an innovation. Other community members are able to access such resources efficiently and comprehend the innovation in time based on the inter-organizational network (Gulati et al., 2000). Different community members will then undertake different activities to take advantage of the information resources wisely (Cohen & Klepper, 1992). For example, technology providers who access such information resources will accordingly make strategic decisions on if joining in the innovation community and competing with other technology providers (Shane, 2001), while adopters are more likely to consider the most fit technologies to use based on the information resources they access. Consultants and other community members will also arrange their relevant plans based on the information spread from technology providers (e.g., how to collaborate with adopters and how to research on the technology). Overall, in the context of an innovation community, different populations are able to more or less use the resources effectively based on the inter-organizational network in which they are embedded. A population with a network structure which can utilize the inter-organizational resources efficiently is able to accommodate more organizations in that population.

Prior work has suggested that the “highly-connected” nodes are very efficient in spreading resources (e.g., information) in the network, and the presence of those

highly-connected nodes help to characterize the scale-free level (and efficiency) of a network (Li et al., 2005). Within an innovation community, technology providers function as highly-connected nodes and make connections with other community members. As detailed in Section 3.4.2, each population's ability to capture resources differently and correspondingly accommodate more entries is dependent on the inter-organizational network. The high efficiency (scale-freeness) of the inter-organizational network would strengthen a population's ability to use different resources or capture resources differently, which allows the population accommodate more entries. Hence,

Hypothesis 5: the organizational entry rate of technology provider is positively associated with the scale-freeness of an innovation community

The exploration of scale-free networks will contribute to understanding value and function of those highly-connected nodes in communities of innovation. The relationship between organizational entry rate and scale-freeness can help us describe the strategic value of those highly-connected nodes (Woodard et al., 2013) and the function of these "control points" (Pagani, 2013) in a scale-free community of innovation. Together with organizational ecology theory, this dynamic evolution of the community structure study may help to explain why some organizations develop or move into such favorable positions while others do not, and describe the overall dynamics of an innovation community.

Chapter 4: Methods

In this dissertation, Customer Relationship Management (CRM) and its associated community is chosen as the site of study. CRM is a term that refers to practices, strategies and technologies that companies use to manage and analyze customer interactions and data throughout the customer lifecycle.⁷ CRM developed in early 1990s as an automation tool to enable organizations to support effective marketing, sales, and service across customer interaction channels, and to maximize customers' long-term value to the enterprise (Greenberg, 2004). CRM is also a category of enterprise software that has been widely adopted across many industries in so many countries (Grodal et al., 2015). Since its launch, the technology of CRM has been significantly reshaped from client-based systems in the late 1990s (i.e. Siebel Systems) to cloud-based systems (i.e. Salesforce) in the early 2000s, and until the recent development of mobile CRM (i.e. SugarCRM) and social CRM (i.e. Nutshell) between 2013 and 2016.⁸ Overall, despite of the technology transformation of CRM over time, CRM is still evolving and considered as a term for describing the interaction between companies and current and/or potential customers.

The CRM innovation community is suitable for this study. First, CRM has existed for more than 10 years and it is still evolving over time. However, the evolution of the innovation community that supports the development of CRM innovation remains unclear. Second, CRM is one of the few enterprise software innovations that have penetrated most industries in so many countries around the

⁷ <http://searchcrm.techtarget.com/definition/CRM> (accessed May 8, 2017)

⁸ <http://comparecamp.com/introduction-history-crm-software/> (accessed May 8, 2017)

world. Therefore, the CRM innovation community has attracted diverse organizational participants from multiple populations that play various roles in producing and using CRM. The activities of different organizations take within the CRM innovation community provide details for us to understand the development of the innovation community itself.

This Chapter documents the concrete research methods used in this dissertation. First, I describe and explain the IT innovation that was studied. I then depict the type and source of data. Third, I detail how the data was collected and processed. Last, I explain how the data was analyzed to test the theoretical models.

4.1. Data Collection

Research on organizational ecology has developed a rich set of effective methods to explain population dynamics (e.g., the relationship between organizational entry rate and organizational density). However, the data collection methods used at population level may not be readily applicable for studying the ecology of an innovation community. This is because organizations from different populations have different characteristics and conduct highly different activities. For instance, while automobile encyclopedias are comprehensive and reliable data sources for studying the ecology of European auto industries (Hannan et al., 1995), rosters of CRM adopters and implementers are not so easy to find. Further, often the scale and dates of the adopter data would not match those of the vendor data, making it difficult to include both the adopters and vendors in one study. Last, participants in the CRM innovation are not usually recognized as legal groups, nor do they have clear definition of “membership”. As a result, the data collection approach to studying the

dynamics of single population/industry can not be directly applied to innovation communities.

A solution to study the ecology of CRM innovation community may derive from the fact that most organizations, despite the different populations they belong to, engage in a discourse, as they comprehend, adopt, and develop an innovation (Swanson & Ramiller, 1997; Wang & Ramiller, 2009). Hence, discourse can serve as the basis for observing participation of organizations in a multi-population innovation community.

4.1.1. Discourse data

A discourse refers to an interrelated set of texts and the practices of producing, disseminating, and receiving these texts (Phillips & Hardy, 2002). The practices and activities then later result in making sense of an object. An innovation's discourse is, therefore, an interrelated set of the texts and the practices of producing, disseminating, and receiving these texts related to an innovation. These practices in discourse help to make sense of the innovation. Organizational participants from different populations engage in an innovation community to affect the shape of the innovation itself, and they simultaneously attempt to agree on a common sense of such innovation (Swanson & Ramiller, 1997). The common sense of an innovation is negotiated, developed, and shaped through discourse over time (Phillips & Hardy, 2002).

Since discourse is shared across population and community boundaries, discourse provides a common basis for observation. Activities in a discourse provide important information to its participants, which manifest the complicated social

resources on which participants must rely on to transfer the innovation from vision to actuality (DiMaggio, 1992). For example, such social resources can be the frequency of mentioning an object, which as Kennedy (2008) described, is a reflection of relatively high attention from participants to an object in a discourse. Therefore, by identifying the participants and their associated activities in the discourse, we can create a representation of the innovation community with a majority of heterogeneous participants focusing on a central object in the discourse (Kennedy, 2008).⁹ Further, prior work has suggested that discourse both reflects and enables the production and use of innovation in an innovation community (Green, 2004; Miranda et al., 2015; Phillips et al., 2004; Ramiller et al., 2008; Suddaby & Greenwood, 2005; Sun & Wang, 2012). Hence, discourse is not only the reflection of activities of innovation community participants, but also a critical part when participants take practices to make sense of an innovation (Swanson & Ramiller, 1997). Overall, the nature of discourse provides a basis for accessing the presence of participants and their associated activities in an innovation community.

4.1.2. CRM as empirical site

CRM is a category of enterprise software that enables organizations to support effective marketing, sales, and service across customer interaction channel, maximizing customers' long-term value to the enterprise (Greenberg, 2004). CRM developed in the early 1990s as an automation tool for improving the efficiency of an organization's sales force. The scope of CRM then expanded to include backbone technologies for enhancing the effectiveness of customer services, especially call

⁹ There may be a small portion of participants that do not focus on the central object as the majority do

center operations. Since the turn of century, CRM has increasingly become a tool for collecting and analyzing customer and business partner data from multiple channels. Siebel Systems dominated the CRM software market in the late 1990s and early 2000s, reaching 46% market share in 2002, but could not fend off fierce competition from cloud-based CRM vendors such as Salesforce.com. Later, Siebel Systems was acquired by Oracle in 2005 and Salesforce.com became the market leader, claiming 16% of the worldwide CRM software market of \$20.4 billion in 2013,¹⁰ according to industry research firm Gartner. U.S., and Europe-based firms in industries such as high-tech, banking, insurance, securities, telecommunications, pharmaceutical, and consumer goods are leading the adoption of CRM software.¹¹

CRM is both a widely adopted digital platform with a layered modular architecture (Yoo et al., 2010) and a notable class of IT (digital) innovation. The potential of CRM lies not only in the product innovations offered by CRM vendors, but also in the numerous process, service, and business model innovations that CRM adopters from diverse industries create based on the core CRM digital platform (Fichman et al., 2014). It is through such adopter-led "organizational co-innovations" that firms can couple new technology with complementary organizational elements to realize and maximize value from CRM (Fichman, 2012). The CRM innovation community is suitable for this study because it has attracted diverse organizational participants from multiple populations that play various roles in producing and using CRM. Second, CRM is one of the few enterprise software innovations that have penetrated most industries in so many countries around the world. So the size and

¹⁰ <http://www.gartner.com/newsroom/id/2730317> (accessed July 8, 2016)

¹¹ <http://www.gartner.com/document/2679218> (accessed July 8, 2016)

diversity of the community participants is sufficient to test and advance ecology theory at the community level. Further, organizational participants of the CRM community struggled to sustain their momentum; many of them made substantial efforts to enter and stay in the community (Wang & Swanson, 2008). Therefore, in addition to the size and diversity of the CRM community, the community also has been subject to significant population dynamics of the type expected by ecology theory and models.

4.1.3. CRM discourse

A CRM discourse is an interrelated set of the texts and the practices of producing, disseminating, and receiving these texts related to CRM. Organizational participants from different populations engage in the CRM innovation community to shape the development of CRM (Swanson & Ramiller, 1997). Since CRM has been widely adopted in many industries around the world over a long time, the long and colorful history of CRM provides us an opportunity to witness how a mature IT innovation and its associated community evolve over time. The CRM discourse not only reflects the activities of innovation community participants, but also plays a significant role in explaining how participants engage in to develop and make sense of CRM. Therefore, to study the ecology of CRM innovation community, the discourse approach provides a basis for accessing the presence of CRM participants and their associated activities in the CRM innovation community.

4.1.4. Source of discourse data

For this study, discourse data was initially collected from *Computerworld*.¹² With a weekly circulation of 165,050 in the first half of 2013,¹³ *Computerworld* is one of the leading trade magazines that focus on issues in IT and other digital technologies. Unlike specialized outlets such as press releases or academic publications, trade magazines such as *Computerworld* capture the opinions and actions of a wide spectrum of actors, including various organizations participating in the CRM innovation community.

The magazine (*Computerworld*) is indexed in several online bibliographic databases. The LexisNexis Academic database was chosen, because besides LexisNexis Academic database's easy search and downloading functions, its indexing of *Computerworld* (1982-2011) covers nearly the whole course of CRM's evolution, from its origin in the early 1990s, over its peak in popularity circa 2002, through its more recent transformation. This study focuses on the ten-year observation window between 1998 and 2007, because CRM attracted significant attention and media coverage during this period. Within LexisNexis, I specified each outlet and searched for the phrase "customer relationship management" in the subject headings assigned to each article published between 1998 and 2007. Each article is assigned multiple subject headings. Each subject of an article carries a percentage value, which indicates the level of relevance of the subject to the article. The search of the news articles resulted in 594 articles whose subject headings include CRM with relevance

¹² Some other outlets such as *New York Times*, *Washington Post*, and *Wall Street Journal* are added to expanded dataset to address the news articles selection issue detailed in Chapter 6.

¹³ http://marketing.computerworld.com/CW_BPA_June2013.pdf (accessed July 8, 2016)

scores. By using the automatic topic modeling process¹⁴ in LexisNexis, 198 news articles that carry 80% relevance score were considered for initial data processing. Articles with CRM subject below 80% were removed because the majority body of the articles only mentioned CRM in passing based on the content reading. Two coders then further read and analyzed the 198 articles independently and agreed to remove 6 articles that did not address the CRM software or technology, leaving 192 articles in the dataset for final processing and analysis.

¹⁴ For more details about LexisNexis's topic modeling see: https://www.lexisnexis.com/infopro/resource-centers/product_resource_centers/b/smartindexing/archive/2013/09/06/relevance-scores-50-99.aspx (accessed Aug 20, 2016)

4.2. Data Processing

The articles in the dataset are processed in three steps. First, the full text of these articles were imported into ATLAS.ti (version 6.0.15), a qualitative analysis software application. Second, organizations involved in any aspect of producing and/or using CRM were identified with a unique name.¹⁵ Third, drawing from the prior innovation community studies (Sun & Wang, 2012; Swanson & Ramiller, 1997; Wang & Ramiller, 2009) and based on the different interests that organizations involved in producing/using CRM in the sample articles, different types of community roles and relationships were identified. For example, for each organization identified, a specific role that such organization played in the CRM innovation community was determined (see the list of community roles and example text from articles in Table 3.1) based on how it was described in the sample articles where the organization was mentioned. Some organizations always play just one role. For example, Siebel Systems was always described as technology provider. Others, however, played more than one role. For instance, some consulting firms not only provided consulting services on CRM but also adopted CRM for their own use.¹⁶

¹⁵ Organizations that have multiple versions of name in the dataset have been renamed to one unique name. For example, I.B.M, IBM, and International Business Machines Corporation were renamed as IBM.

¹⁶ <http://www.computerworld.com/article/2567783/> (accessed July 8, 2016)

Table 3.1 Diverse Roles Organizations Play in the CRM Innovation Community

Role	Sample Organization	Sample Sentence from CRM Articles in <i>Computerworld</i>
Academic Researcher	Temple University	SAP AG's U.S. subsidiary is teaming up with two Temple University professors to develop a benchmarking tool that's designed to help chemical companies assess their customer relationship management (CRM) capabilities. (08/12/2002)
Adopter	Barnes & Noble	As vice president of planning and analysis and new business at Barnes & Noble Inc. in New York, he is using E.piphany's E.5 CRM package to manage and track direct-mail responses and customers' e-mail requests. (06/11/2001)
Consultant	Andersen Consulting and KPMG Peat Marwick	The technology includes computer-telephony integration and interactive voice-response products, call-center and sales force automation technologies as well as middleware and services for integrating and analyzing information gathered from customers. Major companies in this space include IBM, NCR Corp., Unisys Corp. and consulting firms such as Andersen Consulting LLP and KPMG Peat Marwick LLP. (08/17/1998)
Industry Researcher	Forrester Research	In the heavy-truck industry, what's needed is to have a continual view of the status of a vehicle and to provide service to customers on the road," said Steve Cole, an analyst at Forrester Research Inc. in Cambridge, Mass. (11/22/1999)
Technology provider	Siebel Systems	Mentor Graphics, which uses Sales Enterprise from San Mateo, Calif.-based Siebel Systems Inc., is part of a growing trend in sales force automation: companies switching from focusing on process automation to improving the customer's experience. (08/16/1999)

When two or more organizations were mentioned in the same paragraph of an article, the dyadic relationships between them were also coded. Besides random co-occurrences, two organizations may be mentioned together in the same paragraph for a number of reasons. For example, five types of relationships were identified in the coding process, listed in Table 3.2. First, when an organization adopted CRM and its supporting technologies from a technology provider, this relationship was coded as an *adoption*. Second, some organizations teamed up to develop a product package or

portfolio or to implement CRM in *collaboration*. Third, when not collaborating, technology providers tended to engage each other in *competition*. Fourth, like any business-oriented domain, the CRM community is replete with *mergers, acquisitions, and divestitures (MA&D)*. Last, both academic and industry researchers may study particular organizations and thus develop *research* relationships with the subjects of their studies. Using ATLAS.ti., two coders independently coded organizations, community roles, and relationships that appeared in the 192 articles. After coding each article, they compared their coding results, discussed, and reconciled the few differences. The final coding results included 567 unique organizations, with 175 technology providers, 274 adopters, 47 consultants, 64 industry researchers, and 7 academic researchers being identified, respectively. Additionally, 354 *adoption* relationships, 98 *collaboration* relationships, 332 *competition* relationships, 81 *MA&D* relationships, and 137 *research* relationships were coded in 192 articles.

Table 3.2 Types of Relationships between Organizations Co-Mentioned in the Same Paragraph

Relation	Organizations	Sample Sentence from CRM Articles in <i>Computerworld</i>
Adoption	SAP AG and Osram Sylvania	Osram Sylvania Inc., a lighting manufacturer in Danvers, Mass., this spring plans to be one of the first users to install pieces of SAPAG's new customer relationship management (CRM) software. (03/27/2000)
Collaboration	SAP AG and Commerce One	Enterprise resource planning giant SAP AG already publishes many application program interfaces in XML and is working with Commerce One Inc. in Pleasanton, Calif., on a common business library for external transactions. (04/22/2002)
Competition	Youcentric and Siebel Systems	Analysts say Youcentric Inc is a small player in the CRM market, which is dominated by Santa Clara, Calif.-based Siebel Systems Inc. (05/15/2000)
Merger, Acquisition, & Divestiture (MA&D)	Siebel Systems and Janna Systems	January, Siebel said it would extend the buying spree by purchasing Toronto-based Janna in a stock swap valued at \$975 million, based on the Sept. 11 closing price for Siebel's shares. The acquisition of Janna -- which had sales of \$13 million last year and \$12.6 million during the first half of this year -- is expected to be completed in the fourth quarter. (09/18/2000)
Research	Salesforce.com and Forrester Research	Strong integration tools are necessary as Salesforce.com continues to try to move "upmarket" into larger deployments, said Forrester Research Inc. analyst Liz Herbert. (11/30/2006)

In the second step of data processing, all coded organizations, their community roles, and relationships were exported to Microsoft Excel, along with the timestamps of these entities indicated by the publication dates of the news articles. Then the data is split by quarter into 40 sets (representing the 40 quarters between 1998 Q1 and 2007 Q4). To explore the evolution of the CRM innovation community, NodeXL, an Excel add-on module was used to prepare the visualization of temporal organizational networks. The nodes are the organizations and the edges between the

nodes represent their relationships. NodeXL is flexible and versatile, which allows us to group the organizations in each quarter into meaningful clusters by using the clustering function embedded in the software (Hansen et al., 2010). The third step of data processing was to create the dependent variables and independent variables based on ecological models so that the hypotheses could be tested. The procedure is detailed next.

This study focused on entry rate as the primary dependent variable because it measures and explains the variation and growth of a population over a long time period (Baum & Oliver, 1996; Hannan et al., 1995). Examination of organizational entry rate would help us to answer the research question “*how does ecology of an IT innovation community shape the subsequent growth and development of the innovation community*”. Second, by taking the discourse approach (Phillips & Hardy, 2002), it is feasible to define the organizational entry rate. Since the hypotheses in Section 3.3 emphasize specific roles that organizations play in an innovation community, the entry rate of organizations playing specific roles was calculated. In particular, this study focused on the entry rates of technology providers and adopters. This is not only because the participation of technology provider and adopter plays a leading role in encouraging reciprocal collective learning among community members (Wang & Ramiller, 2009) and correspondingly shape the dynamics of CRM innovation community, but also the data of technology providers and adopters are the richest for analysis.

As the hypotheses in section 3.3 suggest, the population variation for each group of organizations are likely to be different by the roles they play, so the adopter

entry rate and technology provider entry rate are treated separately as two dependent variables. Specifically, for organizations that play the role of technology provider in CRM innovation community, the entry rate is measured by the number of technology providers that first appear in the CRM articles in each quarter. Similarly, for organizations that play the role of adopter in CRM innovation community, the entry rate is measured by the number of adopters that first appear in the CRM articles in each quarter. Last, for few organizations that may play more than one roles in CRM innovation community, the entry rate is measured by such organizations playing certain roles that first appear in the CRM articles in a particular quarter.¹⁷

There are two primary independent variables in the density-dependence model: one is density itself as a measure of legitimation; the other is density in its quadratic form, as a measure of competition. In the density-dependence model, the growth of a population is captured by its entry rate (the rate at which new organizations enter the population). The entry rates depend on the number of organizations in a population (density), and the number of organizations is restricted by two ecological processes: legitimation and competition. Legitimation increases entry rate in a population, while competition has the opposite effects (Hannan & Freeman, 1977). Density, the number of organizations in a population, drives both processes, hence the name "density-dependence." This specification allows legitimation to increase at a decreasing rate and competition to increase at an increasing rate (Hannan et al., 1995; Hannan & Freeman, 1993).

¹⁷ <http://www.computerworld.com/article/2567783/> (accessed July 8, 2016)

At the population level, the model has repeatedly proved to be effective in explaining the dynamics of populations. At the community level, as detailed in section 3.3, examination of community dynamics requires us to describe how populations of organizations playing different roles develop within an innovation community. However, empirical evidence in this regard is limited. Sun and Wang (2012) applied the density-dependence model to study the cloud computing innovation community and their results demonstrated the utility of the model at the community level. However, this study did not empirically examine the heterogeneous nature of an innovation community and took into account how different populations in the innovation community developed. Further, cloud computing has been in existence for just a few years and studies at the community level on innovations with longer history such as CRM are warranted.

Following prior studies, two independent variables are included in each analytical model: one for legitimation and the other for competition. However, in the context of news articles about CRM, calculating density is not so straightforward as in traditional studies of population ecology because it is difficult to determine when an organization leaves the population. Although mergers, acquisitions, or bankruptcies of major organizations are reported, those of less well-known organizations and strategic withdrawals from a market space are seldom reported. Considering these issues, different assumptions were made to calculate the density of organizations playing different roles. For technology providers, a 6-month window was employed to monitor presence (and absence).¹⁸ If a technology provider had not

¹⁸ A sensitivity analysis result with a 12-month window and a 18-month window will be reported in Chapter 6.

been mentioned in any article over 6 months, it was assumed to have exited the community. In this way, the number of technology providers still assumed to be in the community each quarter was counted as the density of technology providers. For adopters, because it is unusual for any news agency to report adoption continuously and abandonment of CRM software is even rarer, adopters were assumed not to leave the community. Therefore, density of adopters is the number of adopters recorded cumulatively from quarter to quarter, which follows a classic S-shaped adoption curve (Rogers, 2003).

Since this study involves modeling temporal dynamic processes, the dependent variable (entry rates) in each quarter may be influenced by entry rates in the previous periods, especially the most immediately previous quarter. Therefore, there might be a trending effect, meaning that the entry rate in the present quarter would be similar to the entry rate in the previous quarter. In addition, there might also be an effect similar to that of density. For example, a surge of entries in the previous period might deplete the pool of potential entrants and thus weaken the effect of trending in the current period. Hence, following previous population ecology research (Carroll et al., 1993; Carroll & Swaminathan, 1992), the entry rate in the previous quarter and its quadric form were included as control variables. Further, to control for potential impacts of changes in the environment, five two-year dummy variables were also added in the ecological model in the observation period (1998-2007).

4.3. Data Analysis

Two analytical models were constructed in this study for *Computerworld* magazine. Model 1 is for the technology providers' entry rate using measures of legitimation and competition. The entry rate of technology providers in the previous quarter and its quadratic term were used as control variables. Specifically, Model 1 is constructed to test hypothesis 1 and hypothesis 2.

$$\lambda(t)_{TP} = \beta_1 n_{(t-1),TP} + \beta_2 n_{(t-1),TP}^2 + \beta_3 \lambda_{(t-1),TP} + \beta_4 \lambda_{(t-1),TP}^2 + \sum_{i=1}^4 \gamma_i y_i + \beta_0 \quad (1)$$

where $\lambda(t)_{TP}$ denotes the entry rate of technology providers in quarter t ; $n_{(t-1),TP}$ denotes the number of technology providers (density) in the community in the previous quarter $t-1$; $n_{(t-1),TP}^2$ denotes the quadric form of technology provider density in the community in the previous quarter $t-1$; $\lambda_{(t-1),TP}$ is the entry rate of technology providers in the previous quarter $t-1$; $\lambda_{(t-1),TP}^2$ is the quadric form of entry rate of technology providers in the previous quarter $t-1$; y_i is the dummy variable for the two-year period i (the base 2006-2007; y_1 is for 1998-1999; y_2 for 2000-2001; y_3 for 2002-2003; and y_4 for 2004-2005).

Model 2 uses measures of legitimation and competition to explain the adopters' entry rate. The entry rate of adopters in the previous quarter and its quadratic term were used as control variables. Specifically, Model 2 is constructed to test hypothesis 3 and hypothesis 4

$$\lambda(t)_A = \beta_1 n_{(t-1),A} + \beta_2 n_{(t-1),A}^2 + \beta_3 \lambda_{(t-1),A} + \beta_4 \lambda_{(t-1),A}^2 + \sum_{i=1}^4 \gamma_i y_i + \beta_0 \quad (2)$$

where $\lambda(t)_A$ denotes the entry rate of adopters in quarter t ; $n_{(t-1),A}$ denotes the number of adopters (density) in the community in the previous quarter $t-1$; $n_{(t-1),A}^2$ denotes the quadric form of adopter density in the community in the

previous quarter $t-1$; $\lambda_{(t-1),A}$ is the entry rate of adopters in the previous quarter $t-1$; $\lambda_{(t-1),A}^2$ is the quadric form of entry rate of adopters in the previous quarter $t-1$; y_i is the dummy variable for the two-year period i (the base 2006-2007; y_1 is for 1998-1999; y_2 for 2000-2001; y_3 for 2002-2003; and y_4 for 2004-2005).

Chapter 5: Preliminary Study

This chapter first describes how the CRM innovation community evolved during the observation period and explains why the community evolved that way. Then, I apply organizational ecology to empirically examine how populations of technology providers and adopters developed within the CRM innovation community. Last, this chapter ends with some limitations in the preliminary study and calls for additional analysis to address such limitations in next chapter.

5.1. Evolution of the CRM Innovation Community

The ten-year observation period (1998-2007) was an interesting period for IT innovations and their associated communities. It was a period when the dot-com bubble peaked and then burst and when many firms adopted new enterprise systems such as ERP and CRM. The most prominent organizations in the populations of technology providers and adopters in the CRM innovation community are summarized in Table 5.1. Within the CRM innovation community, for example, ERP was the leading enterprise software that most organizations adopted in the late 1990s, CRM was an important part of the community. In addition to developing and offering CRM as a primary focus in the later period, IBM and SAP were two of the largest ERP systems vendors that received relative public attention in the CRM innovation community during the period 1998-1999. IBM and SAP became the most visible organizations in the CRM innovation community given the prominence of ERP. Overall, in the last two years of the 1990s, CRM innovation community accommodated 53 technology providers in the sampled articles with IBM and SAP

leading the crowd. On the other side, 59 adopters from diverse industries were mentioned in the sampled articles.

After 2000, these dedicated CRM vendors rose in prominence in the CRM innovation community, as Siebel Systems came to the public eye. The CRM innovation community began to grow and this momentum accelerated during the period 2000-2001 when more technology providers, adopters, and others joined the community. Specifically, the entry rate of technology providers reached its peak in 2000 and was followed by the peaks of adopters' entry rate in 2001 and the peak of discourse volumes as measured by paragraph count in 2002 (Figure 5.1).

The most notable CRM technology provider in period 2000-2001 is Siebel Systems. Siebel Systems was adopted by many different companies in different industries for improving the efficiency of their sales force. In developing and shaping CRM as a successful innovation, Siebel Systems has been one of the most important contributors for this IT innovation, but it did not work alone. Forming strategic alliances with different companies (e.g., American Management Systems, i2 Technologies Inc., and Manugistics Group Inc) to strengthen its e-business solutions and working with management consulting firm (e.g., PwC) to help its customers comprehend the innovation are the primary business strategies Siebel Systems adopted, yet it only reveals half of the puzzle. And more importantly, competitions among CRM technology providers motivated Siebel Systems to make sustained improvements on its CRM technology for leading the CRM innovation community. For example, Siebel Systems developed a CRM software package named Siebel eBusiness 2000 to compete with other CRM technology providers such as SAP and

Oracle during the period 2000-2001. The Siebel eBusiness package allowed firms to manage sales, marketing, and customer service across all communication channels including the Web, call center, field sales and service, and reseller channels.¹⁹ Similarly, other technology providers had to develop the CRM software with new features to compete with Siebel Systems. For instance, around 2000, Oracle recognized the fast growth of Siebel Systems in the CRM innovation community and announced that it would create technician and sales groups for improving its CRM software. Siebel Systems, in response, claimed that it would surpass Oracle in applications. Later, Siebel Systems added web-conferencing and document-sharing capabilities provided by ActiveTouch Inc to its Software package.

In the period of 2002-2003, Siebel Systems became the focus of CRM innovation community after it acquired a couple of small CRM vendors such as UpShot Corp, Edocs, Inc, OnTarget Inc, and Scopus Technology to provide business solutions for its software and related areas.²⁰ Meanwhile, Siebel Systems continued to work with companies such as Active Software Inc for adding new features on its software and Keane Inc for providing related technology supports & consulting services to Siebel Systems adopters. By the end of 2002, Siebel Systems dominated the CRM software market in the CRM innovation community, reaching 46% market share with total revenue over \$1 billion. Acquisitions and alliances were the two primary “secrets” that accelerated the growth of Siebel Systems in the CRM innovation community.

¹⁹ <http://www.fundinguniverse.com/company-histories/siebel-systems-inc-history/> (accessed July 8, 2016)

²⁰ <http://www.fundinguniverse.com/company-histories/siebel-systems-inc-history/> (accessed July 8, 2016)

During the period 2004-2007, the form of information technology was significantly reshaped including CRM. It was a period when a new crop of technology companies that remain dominant in today's economy, such as Facebook and Twitter, were founded. Within the CRM innovation community, it was a period when the once largest CRM vendor Siebel Systems was acquired by Oracle given its considerable turmoil caused by operation issues and fierce competition from other competitors such as Salesforce.com, SAP and Microsoft.²¹ It was also an important period when a couple of cloud-based CRM technology vendors such as Salesforce.com and SugarCRM.com joined in the CRM innovation community and then later became to dominate the market. The initial public offering of Salesforce.com was listed on the New York Stock Exchange in June 2004. Salesforce.com joined in the CRM innovation community as a cloud-based CRM technology provider when the cloud-based technology became applicable and adopters began to abandon the client-based CRM systems.²²

Siebel Systems was acquired by Oracle in 2005 with \$5.8 billion and exited from the CRM innovation community not only because of its own operation issues, but also because it could not fend off the fierce competition from cloud-based CRM vendors such as Salesforce.com and SugarCRM.com. By adopting similar business strategy as Siebel Systems did, Salesforce.com acquired small technology vendors²³ (e.g., Kieden, Sendia, and Jigsaw Data Corp) to strengthen its cloud-based CRM technology feature and formed partnerships with different companies (e.g.,

²¹ http://www.nytimes.com/2005/09/12/business/oracle-to-acquire-siebel-systems-for-585-billion.html?_r=0 (accessed July 28, 2016)

²² <http://www.referenceforbusiness.com/history2/84/salesforce-com-Inc.html> (accessed July 28, 2016)

²³ <https://en.wikipedia.org/wiki/Salesforce.com> (accessed July 28, 2016)

AppExchange and Accenture) to provide its users with technology supports and consulting services. However, unlike Siebel Systems which could not adapt to the environment and correspondingly change its core CRM technology, Salesforce.com was more likely to survive and evolve. One possible reason is that salesforce.com adapted itself to the environment which calls for the cloud-based technology during that time period (Hannan & Freeman, 1993; Levinthal, 1991; Rao & Singh, 1999). In fact, Salesforce.com claimed 16% of the worldwide CRM software market of \$20.4 billion in 2003, which was considered as a great success in the CRM industry. Later in 2006, Salesforce.com became the market leader in the CRM innovation community and formed a primary trio competition relationship with Oracle and SAP. However, the colorful history of Salesforce.com did not end within the ten-year observation period. For example, year 2013 was another milestone for Salesforce.com, as it claimed 16% of the worldwide CRM software market of \$20.4 billion.²⁴ Figure 5.1 summarized the major events detailed above in the ten-year observation period.

On the CRM adopter side, there was a steady increasing: 127 new adopters were mentioned in the sampled articles in period 2000-2001 and 80 new adopters were mentioned in the sampled articles in period 2002-2003 respectively, compared to 59 adopters in period 1998-1999. However, if taking the CRM innovation community into account as a whole, starting in 2001 and 2002, the CRM innovation community began to show signs of decline with fewer new organizations joined in a dwindling CRM discourse, as corroborated by Figure 5.1.

²⁴ <http://www.gartner.com/newsroom/id/2730317> (accessed July 28, 2016)

With respect to the presence of adopters in CRM innovation community, we are able to see several adopters which are the industry giants in their own industries. The presence of these adopters in Table 5.1 suggests their reliance on CRM technology. For example, People Energy (now Integrys Energy Group) is the industry leader in natural gas production & supply, and BankAmerica (now Bank of America) is the second largest banks in the US. Both of the companies have thousands of clients, so the application and satisfaction of CRM is of great importance to them for keeping their clients. As a very important community member in the CRM innovation community, the user experience of clients and feedback from adopters about CRM motivate technology providers to improve and shape the CRM technology overtime.

Overall, technology providers in the CRM innovation community are not only affected by the direct interactions such as collaborations with community participants (e.g., PwC from consultant population) and competitions among themselves, but also by the feedback processes from other community participants such as adopter, as expected in organizational ecology theory (Hannan & Freeman, 1993). More importantly, as different community members stay in the CRM innovation community and start to play their roles, the CRM innovation gains legitimacy, which in turn, attract even more organizations join in the CRM innovation community to further make sense of the innovation (Swanson & Ramiller, 1997). Therefore, CRM and its associated community continue to evolve, as its community members develop over time. The evolution pattern of the community that supports CRM allows us to better comprehend how the CRM innovation is developed and shaped.

The next section will explore the network structure of CRM innovation community and explain how different inter-organizational relationships help to shape the CRM innovation community.

Figure 5.1 Trajectories of CRM Discourse Volume and Entry Rates in Computerworld & Events in the CRM Innovation Community 1998-2007

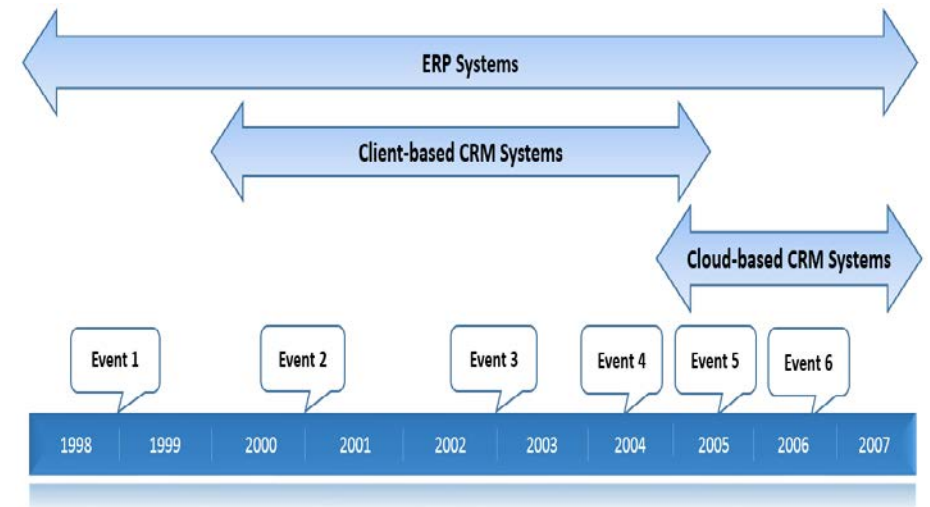
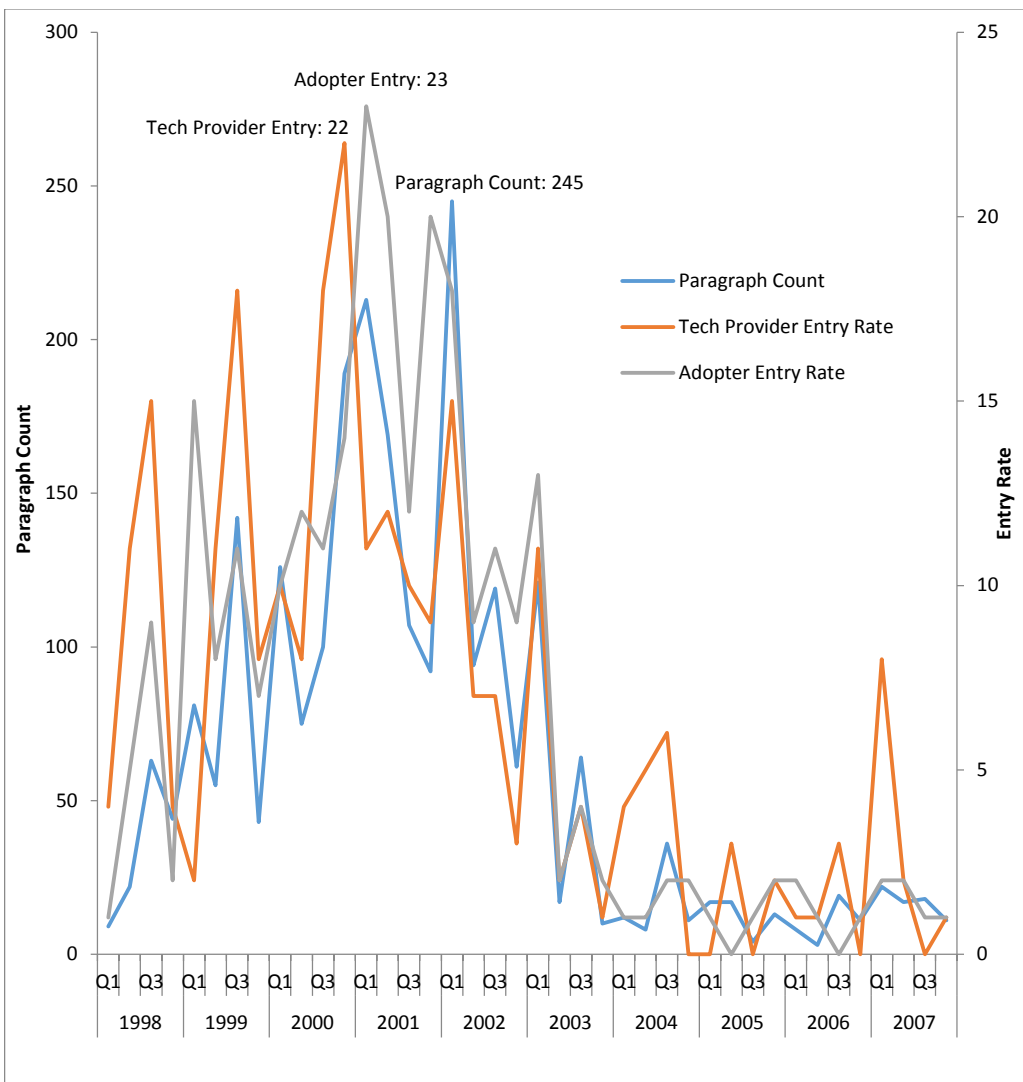


Table 5.1 Most Frequently Mentioned Tech Providers and Adopters

		Tech Providers		Adopters	
		Organization	Freq.*	Organization	Freq.*
1998-1999	1	IBM	19	Peoples Energy	11
	2	SAP	14	BankAmerica	10
	3	Oracle	8	Volvo	8
	4	Vantive	7	Scudder Investor Services	6
	5	Siebel Systems	6	Charles Schwab	5
	53 tech providers in this period			59 adopters in this period	
2000-2001	1	Siebel Systems	56	BankAmerica	11
	2	SAP	29	FedEx	11
	3	PeopleSoft	27	FleetBoston Financial	11
	4	Clarify	25	General Motors	11
	5	Oracle	23	Saks	10
	85 tech providers in this period			127 adopters in this period	
2002-2003	1	Siebel Systems	85	Mitsubishi	12
	2	SAP	44	Countrywide	9
	3	PeopleSoft	28	WH Smith	8
	4	Microsoft	28	Alaska Airlines	7
	5	IBM	15	Xerox	7
	49 tech providers in this period			80 adopters in this period	
2004-2005	1	Siebel Systems	29	Best Buy	3
	2	Salesforce	11	FedEx	3
	3	Clarify	3	Office Depot	3
	4	E.piphany	3	Blue Cross and Blue Shield	2
	5	SAP	3	Pitney Bowes	2
	15 tech providers in this period			16 adopters in this period	
2006-2007	1	Salesforce	44	Stratus Technologies	4
	2	Microsoft	18	MediaBound	2
	3	SAP	14	Siemens	2
	4	Oracle	8	Cast Iron Systems	1
	5	SugarCRM	5		
	13 tech providers in this period			4 adopters in this period	
		175 tech providers in 10 years		274 adopters in 10 years	

* The column shows the numbers of paragraphs from Computerworld containing the corresponding organizations.

5.2. Network Structure of CRM Innovation Community

As detailed in Chapter 2 and Chapter 3, organizations engage in various activities to make sense of an innovation and correspondingly form different inter-organizational relationships in an innovation community. These inter-organizational relationships make organizations more interdependent and shape the structure of an innovation community over time. Therefore, in addition to general trends depicted in section 5.1, the detailed dynamic community structure is also of great importance for understanding the evolution of CRM innovation community.

To explore the network structure of CRM innovation community, NodeXL, a network analysis tool, was used for visualization. For example, Figure 5.2 depicts the community structure as reflected in the *Computerworld* in Quarter 3 of 1998. The nodes in this network diagram are organizations and the edges are the relationships among them. The colors of the nodes represent the different roles these organizations played in the community, as described in Table 3.1. The size of each node indicates the prominent organizations that were mentioned in paragraphs, as detailed in Chapter 4. In this figure IBM is the largest node because it was mentioned more frequently than any other organization in this quarter. This is a *multi-modal network* since multiple types of relationships are shown in the figure. The colors and shapes of the edges indicate the different relationships described in Table 3.2. The thickness of the edges signals the frequency of the specific relationship (e.g., competition and collaboration) being mentioned in the sampled articles.

In order to characterize how inter-organizational relationships and community roles help to shape the structure of CRM innovation community, we need to look at

how the majority of organizations (nodes) function and interact with each other. One solution is to examine the clusters/groups based on inter-organizational relationships within the CRM innovation community. NodeXL allows collections of nodes in a network to be grouped into meaningful clusters with peripheral nodes being filtered out. The clusters can be defined by the existing attributes of the nodes such as the role each organization played in the CRM community (Hansen et al., 2010). In addition, NodeXL can detect clusters for the researchers by automatically assigning densely connected organizations into clusters based on decision rules specified by clustering algorithms from the Stanford Network Analysis Platform (SNAP).²⁵

The clustering function is used to detect groups which have densely connected organizations interacting with each other. For example, NodeXL detected six clusters shown in the boxes in Figure 5.2. In the cluster in the upper left box, six technology providers (Siebel Systems, Baan, Clarify, Onyx Software, Vantive, and Pivotal) had competitive relationships with each other and were all being researched by the industry research firm Gartner. Additionally, Indus International adopted the CRM technology from Vantive. This is a typical example of *multi-modal network* since more than one type of relationship (research relationship, adoption relationship, and competition relationship) is shown in one cluster. On one hand, this network structure shows that in 1998 Q3, technology providers are likely to compete with each other within the CRM innovation community. On the other hand, the network structure detects the participation and engagement of technology providers, adopters, and industry researchers within the CRM innovation community in the same period.

²⁵ <http://snap.stanford.edu> (accessed July 14, 2016)

In the upper right box, in addition to the competitive relationships among the technology providers, large CRM vendor such as IBM acquired smaller CRM vendor, coincided with the business strategy that Siebel Systems adopted (detailed in section 5.1) in its early stage of development. Notably, in the trio cluster represented by a triangle in the middle box in the middle row, Microsoft and Oracle had both competitive and collaborative relationship at the same time, typical for burgeoning technologies with layered modular architecture (Yoo et al., 2010).

Overall, the network structure of CRM innovation community in 1998 Q3 reveals the *multi-modal network* formed by organizations playing diverse community roles and their associated inter-organizational relationships. Three community roles and five inter-organizational relationships are identified in the NodeXL network visualization. The competition relationship is the most common one formed in the network. As expected from organizational ecology theory, technology providers had to compete with each other to survive and occupy the market (Hannan & Freeman, 1993), although such competition may not be intensive given the sufficient available resources in the early stage of CRM evolution within the innovation community (Freeman & Hannan, 1983). In addition to competition, research and MA&D relationships are also prevalent, as industry researchers want to comprehend the CRM innovation and technology providers want to expand their business. Adoption relationship is not observed frequently in the early stage of developing CRM, which may be because adopters want to stay a while and choose the most suitable technology provider later (Swanson & Ramiller, 2004).

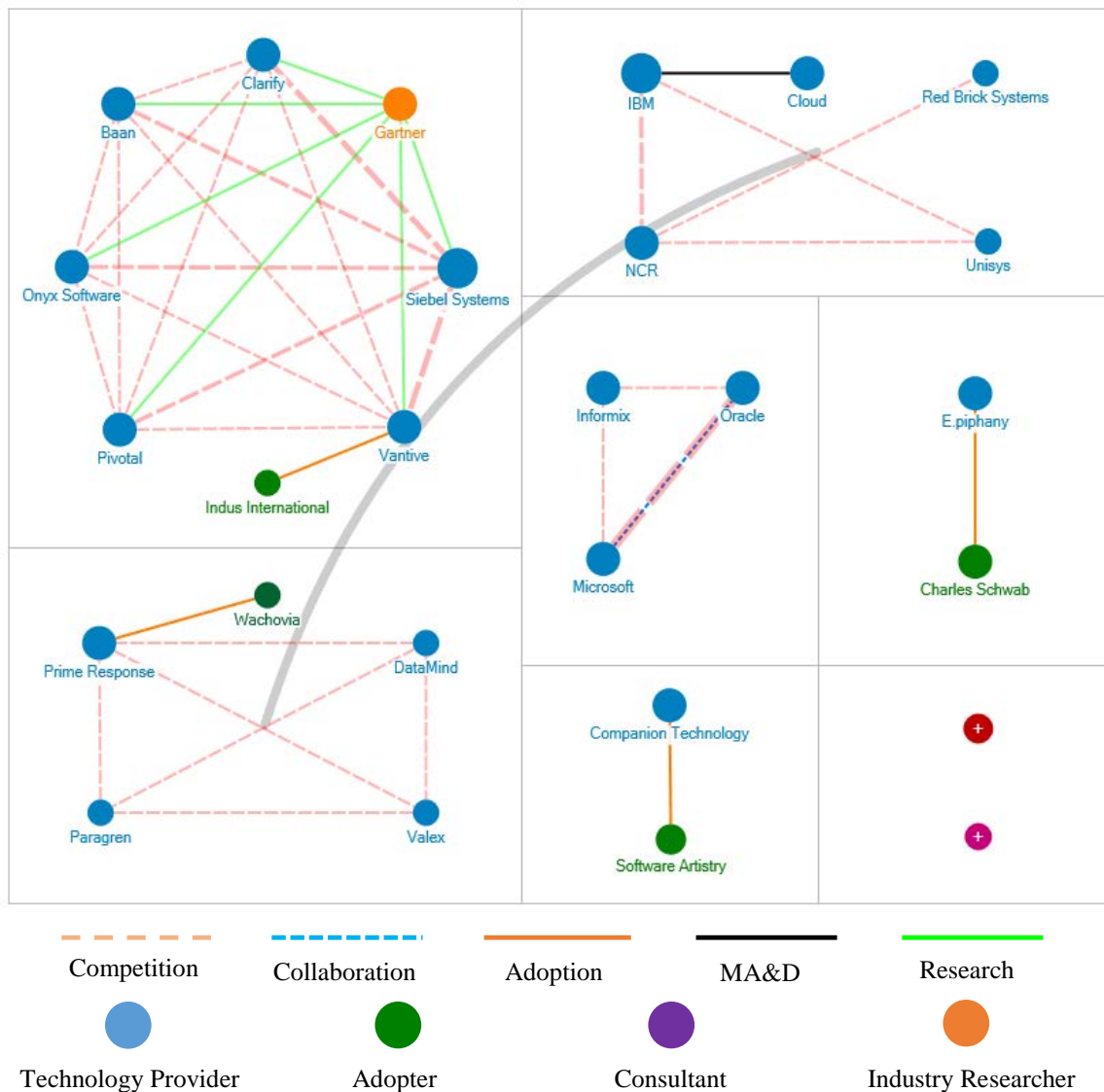
When the CRM innovation community had the most published discourse activities in 2002 Q1, many more organizations, playing different community roles with far more complex relationships were present in the CRM innovation community, as depicted in Figure 5.3. There are 8 clusters, showing the details of the six, and collapsed the other two which had peripheral nodes in the lower right box. In the cluster in the upper left box, four large CRM technology providers (Siebel Systems, SAP, Microsoft, and Oracle) formed a quadruple competition relationship. The competition relationship among technology providers is more prominent, as available resources were consumed over time. Notably, in order to grow and develop in the CRM innovation community, Microsoft acquired small CRM vendor (Great Plains Software) and meanwhile formed both competitive and collaborative relationships with Siebel Systems and Oracle. Microsoft's business strategy attracted the attention from industry researchers and was researched by both Garner and International Data Corporation (IDC). Further, as an indication of innovation community evolution (Swanson & Ramiller, 1997), a joint adoption (between adopter and technology) and collaboration (between adopter and consultant) relationship have appeared in 2002 Q1. For example, Ikon Office Solutions adopted the CRM technology from Oracle and meanwhile worked with consultant Infosys Technologies to better make use of the technology. Last but not least, in addition to the growth of organizations and their associated inter-organizational relationships manifested in the CRM innovation community, another indication of innovation community evolution is the presence of clusters linked by grey line in network structure of 2002 Q1. In NodeXL, the clustering function is used to detect groups which had densely connected

organizations interacting with each other. The gray lines linking the clusters represent the edges that link the nodes in different clusters. Therefore, the presence of gray line suggests organizations not only build connections within the clusters but also build connections among clusters. For example, the competitive relationship between Siebel Systems and PeopleSoft, in separate clusters in the first column, was mentioned in three articles published in 2002 Q1. Such competitive relationship suggested that other CRM technology provider (PeopleSoft) was growing in the CRM innovation community and began to compete with existing CRM technology provider (Siebel Systems), as the CRM innovation community evolved over time.

Later on, the community seemed to present a simple structure as both the number of articles about CRM and the number of organizations mentioned in those articles declined, as shown in 2007 Q2 (see Figure 5.4 and compared to Figure 5.2 and Figure 5.3). The simple community network structure may be due to the MA&D occurred within the CRM innovation community over time (1998-2007), and as a result, the most prominent CRM technology providers were able to survive and stay in the community, while others exited. Second, as organizing vision theory expects (Swanson & Ramiller, 1997), an innovation community is likely to be observed with less activities taken by organizations to shape an innovation when such innovation becomes mature or is institutionalized (Scott, 1995; Suddaby & Greenwood, 2005). Last but not least, such a simple community network structure is a methodological consequence, as the number of articles collected declined over time in the observation period (1998-2007).

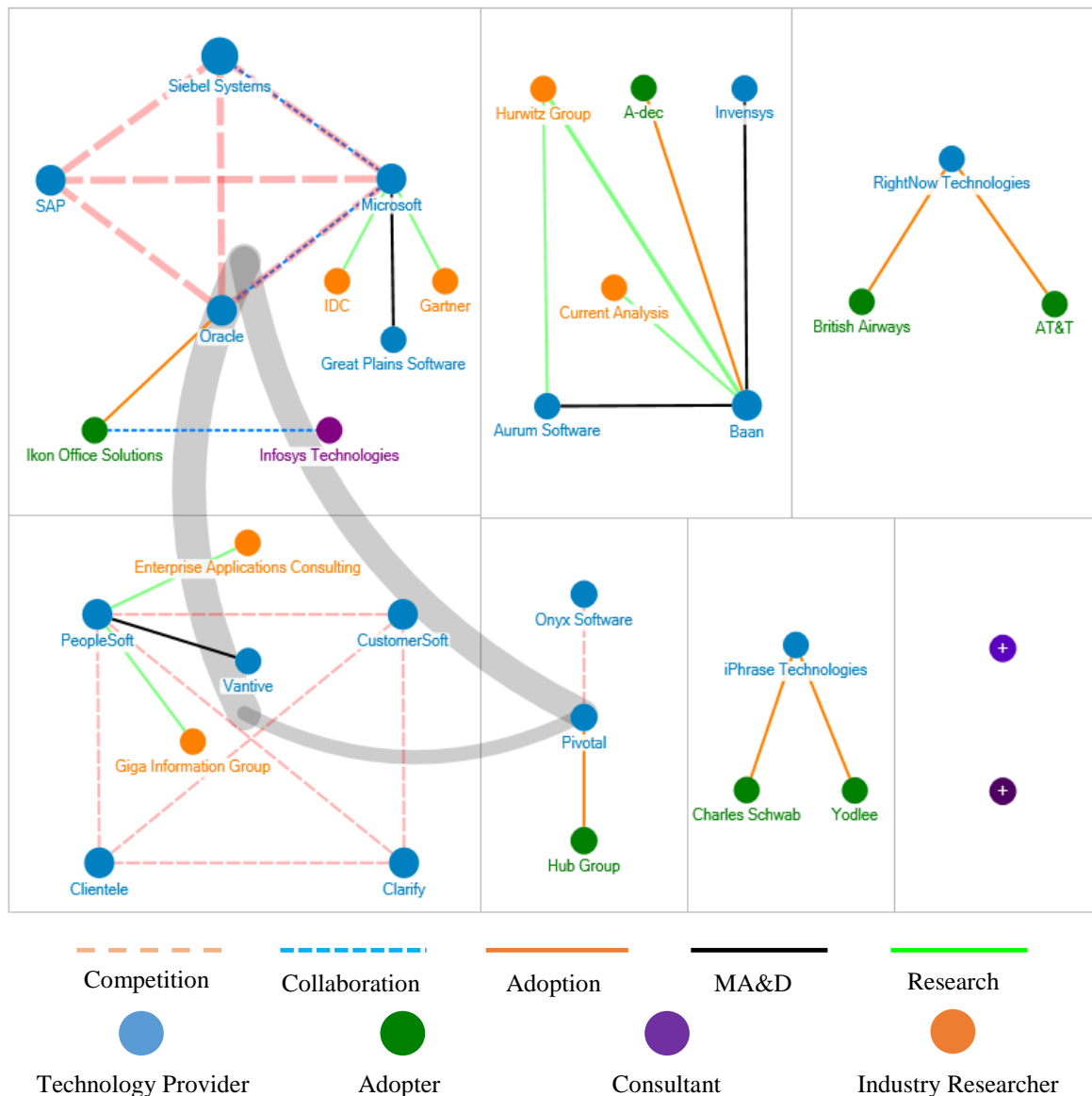
To sum, there are many factors that affect how the technology provider and adopter population develop and grow. Section 5.1 describes the ecological changes of organizations and the CRM innovation community. Section 5.2 depicts the dynamic community network structure. But how does the composition within an innovation community shape its subsequent development? What might explain such seemingly different activities that brought about the overall decade-long trajectory of CRM innovation community? The results of regression analysis will tell the rest of the story.

Figure 5.2 CRM Innovation Community Reported in Computerworld in 1998 Q3



- Color of nodes represents the community role (Table 3.1); size of nodes represents the number of paragraphs where the organization was mentioned during this period: e.g., Red Brick Systems was mentioned in 1 paragraph and Siebel Systems was mentioned in 7 paragraphs.
- Color of edges represents the relationship (Table 3.2); thickness of edges represents the number of paragraphs where the pair of organizations with this relationship was mentioned during this period: e.g., the Informix-Microsoft competition relationship was mentioned in 1 paragraph and the Siebel Systems-Vantive competition relationship was mentioned in 3 paragraphs.
- Gray lines linking the clusters in the figure represent the edges that link the nodes in different clusters. For example, the IBM-Prime Response competition relationship was mentioned in 1 paragraph.

Figure 5.3 CRM Innovation Community Reported in Computerworld in 2002 Q1



- Color of nodes represents the community role (Table 3.1); size of nodes represents the number of paragraphs where the organization was mentioned during this period: e.g., Infosys Technologies was mentioned in 1 paragraph and Siebel Systems was mentioned in 13 paragraphs.
- Color of edges represents the relationship (Table 3.2); thickness of edges represents the number of paragraphs where the pair of organizations with this relationship was mentioned during this period: e.g., the PeopleSoft-CustomerSoft competition relationship was mentioned in 1 paragraph and the Microsoft-Siebel Systems competition relationship was mentioned in 2 paragraphs.
- Gray lines linking the clusters in the figure represent the edges that link the nodes in different clusters. For example, the PeopleSoft-Siebel Systems competition relationship was mentioned in 3 paragraphs.

Figure 5.4 CRM Innovation Community Reported in Computerworld in 2007 Q2



- Color of nodes represents the community role (Table 3.1); size of nodes represents the number of paragraphs where the organization was mentioned during this period: e.g., SAP was mentioned in 2 paragraphs and Salesforce was mentioned in 6 paragraphs.
- Color of edges represents the relationship (Table 3.2); thickness of edges represents the number of paragraphs where the pair of organizations with this relationship was mentioned during this period: e.g., the IBM-Oracle competition relationship was mentioned in 1 paragraph and Salesforce-NetSuite competition relationship was mentioned in 3 paragraphs.
- Gray lines linking the clusters in the figure represent the edges that link the nodes in different clusters. For example, the Oracle-Salesforce competition relationship was mentioned in 2 paragraphs.

5.3. Ecological Explanation of the CRM Innovation Community Evolution

The descriptive statistics of the variables are in Table 5.2. In the ten-year observation period, on average, 6.48 technology providers and 6.70 adopters entered the CRM community each quarter. The community, on average, accommodated 14.80 technology providers and 164.52 adopters each quarter. Some correlations are statistically significant, raising the concern of multicollinearity. To minimize this problem, highly correlated pairs, such as entry rate of technology provider and entry rate of adopter, prior entry rate of technology provider and prior entry rate of adopter, were not included in the same regression model, thus posing no problem. Others variables such as the density and its quadratic forms are expected to have high correlations with each other given the application of density-dependence model (Booth, 1995; Hannan & Freeman, 1977). This is because, in organizational ecology studies, density-dependence model uses the number of organizations (density) to capture legitimation and its quadratic forms (density²) to capture competition (Hannan et al., 1995). These two constructed measures are thus expected to be highly correlated with each other in the density-dependence model. Therefore, before the regression analysis, the tolerance values of explanatory variables were calculated and issues of multicollinearity were tested for each regression model. The results showed that the tolerance of each regression model was above 0.10 (O'Brien, 2007) and the condition index (CI) was below 30 (Fréchette & Daigle, 2002), suggesting no serious problem of multicollinearity in the analysis.

Table 5.2 Descriptive Statistics of Main Variables in Computerworld

	Mean	S.D.	1	2	3	4	5	6	7	8	9
Dependent Variables (t)											
1 Entry rate (tech provider)	6.48	5.71									
2 Entry rate (adopter)	6.70	6.49	0.68**								
Independent Variables (t-1)											
3 Density (tech provider)	14.80	11.89	0.74**	0.82**							
4 Density ² (tech provider)/1000	0.36	0.40	0.70**	0.80**	0.98**						
5 Density (adopter)	164.52	81.27	-0.51**	-0.34**	-0.46**	-0.39**					
6 Density ² (adopter)/1000	33.51	21.28	-0.61**	-0.48**	-0.59**	-0.53**	0.98**				
Control Variables (t-1)											
7 Prior entry rate (tech provider)	6.37	5.64	0.56**	0.64**	0.82**	0.81**	-0.39**	-0.50**			
8 Prior entry rate ² /1000 (tech provider)	0.07	0.11	0.48**	0.56**	0.69**	0.67**	-0.34**	-0.44**	0.94**		
9 Prior entry rate (adopter)	6.67	6.51	0.58**	0.75**	0.87**	0.87**	-0.21	-0.34*	0.69**	0.58**	
10 Prior entry rate ² /1000 (adopter)	0.09	0.13	0.48**	0.68**	0.75**	0.79**	-0.16	-0.23	0.56	0.46**	0.95**

t=1, 2, ..., 40 (1998Q1-2007Q4)

*: p<0.05; **: p<0.01; two-tailed tests

Period dummy variables are omitted.

In this study, our dependent variables, technology provider and adopter entry rate, are count variables. In general, poisson regression and negative binominal regression are more effective for predicting count dependent variables (Cameron & Trivedi, 1998; Swaminathan, 1995). To test which regression model (i.e., poisson regression and negative binominal regression) is more suitable for this study, histograms of the dependent variable (entry rate of technology provider and adopter) were created to review general data distribution. The results showed that neither the entry rate of technology providers, nor the entry rate of adopters is normally distributed (Figure 5.5), indicating additional tests should be conducted to further examine the data distribution (Cameron & Trivedi, 1998). Then, the average entry rate of technology providers and adopters were calculated for each two-year time segments in the ten-year observation period. The results (Table 5.3) showed that the mean value of the entry rates (technology provider and adopter) varied by time period. More importantly, the conditional variance exceeded the mean of both technology provider and adopter entry rates, which suggested that the dependent variable was over-dispersed (Cameron & Trivedi, 1998; Swaminathan, 1995). Therefore, negative binominal regression, which is best suited for explaining over-dispersed count dependent variables, was used. The results of the negative binominal regressions based on the two analytical models described above are shown in Table 5.4.

Figure 5.5 Histograms of Technology Providers and Adopters' Entry Rate in Computerworld

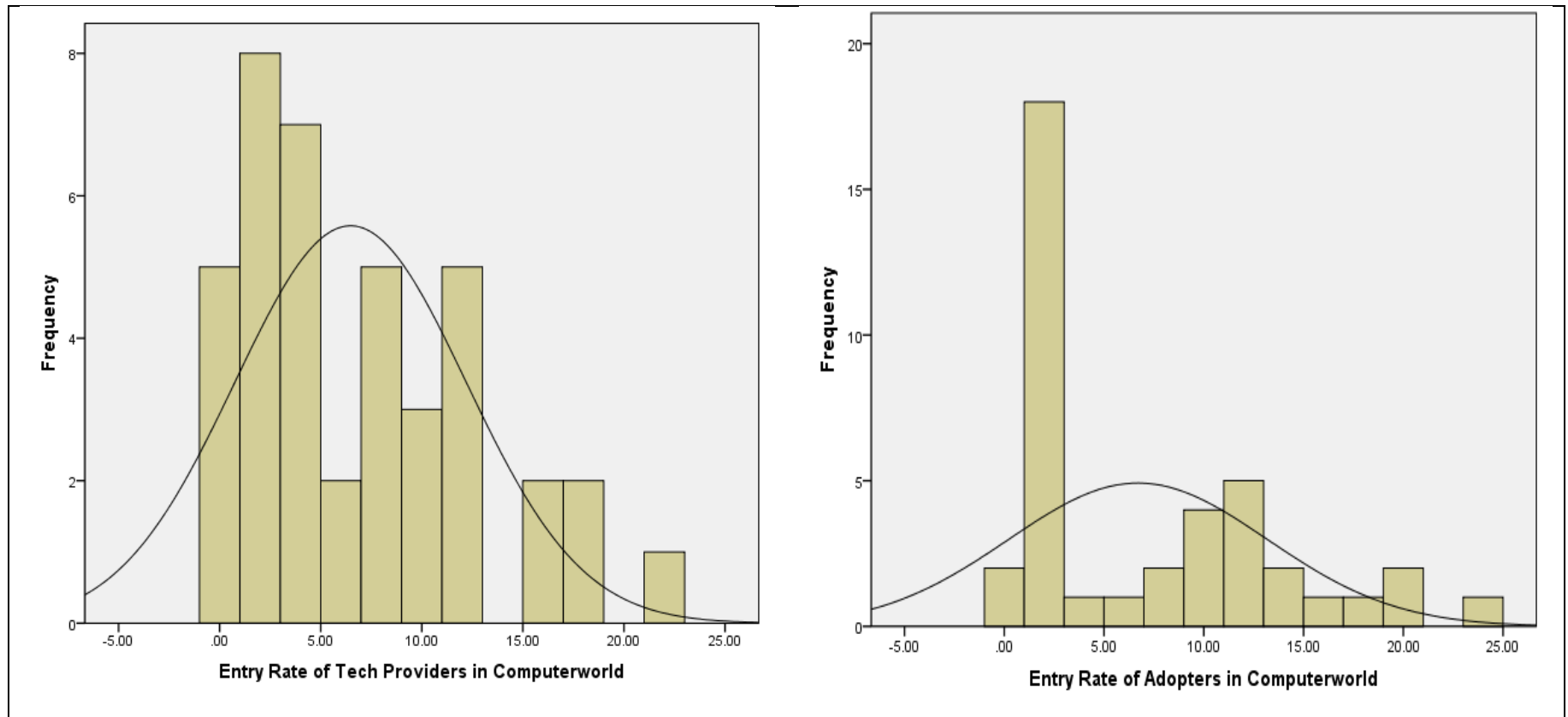


Table 5.3 Over-dispersion Test on Entry Rate of Technology Providers and Adopters in Computerworld

Entry Rate of Technology Provider by Time Period			
Time Period	Mean of Entry Rate	Number of Quarters	Conditional Variance
1998-1999	9.125	8	32.125
2000-2001	12.500	8	24.000
2002-2003	6.250	8	23.071
2004-2005	2.500	8	5.714
2006-2007	2.000	8	6.857
Entry Rate of Adopter by Time Period			
Time Period	Mean of Entry Rate	Number of Quarters	Conditional Variance
1998-1999	7.250	8	21.357
2000-2001	15.250	8	24.786
2002-2003	8.500	8	31.714
2004-2005	1.250	8	1.530
2006-2007	1.150	8	1.750

Table 5.4 Results of Negative Binominal Regression on Community Entry Rate in Computerworld

	Dependent Variable (t)			
	Model 1 Entry rate (tech provider)		Model 2 Entry rate (adopter)	
Independent Variables (t-1)	Coefficient	S.E.	Coefficient	S.E.
Density (tech provider)	0.23 ***	0.05		
Density ² (tech provider)/1000	-3.83 ***	1.36		
Density (adopter)			0.03 *	0.03
Density ² (adopter)/1000			-0.11 *	0.06
Control Variables (t-1)				
Prior entry rate (tech provider)	-0.17 **	0.09		
Prior entry rate ² /1000 (tech provider)	5.16	3.17		
Prior entry rate (adopter)			0.01	0.08
Prior entry rate ² /1000 (adopter)			0.32	2.75
Period (1998-1999)	0.31	0.44	1.99 **	0.81
Period (2000-2001)	0.17	0.51	1.52 **	0.66
Period (2002-2003)	-0.24	0.42	1.46 ***	0.49
Period (2004-2005)	0.28	0.45	-0.09	0.27
Analytical model tolerance	0.0861		0.0876	
Akaike's Information Criterion (AIC)	231.909		225.521	
Pearson Chi-Square (df)	13.60**(31)		7.71**(31)	

t=1, 2, ..., 40 (1998Q1-2007Q4)

*: p<.05; **: p<.01; ***: p<.001 (one-tailed test)

Model 1 considers and explains the entry rate of technology providers. Pearson Chi-square is 13.60 and suggesting the overall model is significant. Additionally, Akaike's Information Criterion (AIC) is 231.909²⁶ (positive), suggesting the overall model effectively explains the entry rate of technology providers (Aho et al., 2014). In Model 1, the prior entry rate of technology providers, as a control variable, is significant ($\beta = -0.17$; $p \leq 0.01$). The legitimization measure (density of the technology providers) has a positive significant association with entry rate ($\beta = 0.23$; $p \leq 0.001$), whereas the competition measure (the quadratic form) has a negative significant association with entry rate ($\beta = -3.83$; $p \leq 0.001$). These results suggest that Hypotheses 1 and 2 are supported.

Model 2 is exclusively based on adopter data and explains the entry rate of adopters. Pearson Chi-square is 7.71, indicating the overall model is significant. Additionally, Akaike's Information Criterion (AIC) is 225.521 (positive), suggesting the overall model effectively explains the entry rate of adopters. In Model 2, the negative binominal regression results shows that three out of the four period dummies, as control variables, are significant (Period 1998-1999, $\beta = 1.99$; $p \leq 0.01$; Period 2000-2001, $\beta = 1.52$; $p \leq 0.01$; Period 2002-2003, $\beta = 1.46$; $p \leq 0.001$). The results in this model are similar to those in the first model: significant positive effect of legitimization ($\beta = 0.03$; $p \leq 0.05$) and significant negative effect of competition ($\beta = -0.11$; $p \leq 0.05$) on adopters' entry rate. Regression results based on adopter data indicate that Hypotheses 3 and 4 are supported as well.

²⁶ All information criteria are in smaller-is-better form. AIC is smaller than the other information criteria in the regression results

Together these models provide support for the hypotheses (summarized in Table 5.5). Overall, for organizations participating as technology providers and adopters in the CRM innovation community, legitimation attracts organizational entries but competition deters them.

Table 5.5 Summary of Hypotheses Tests in Preliminary Study

	Results
H1. The entry rate of organizations that play the role of technology provider is positively associated with legitimation in an IT innovation community.	Supported
H2. The entry rate of organizations that play the role of technology provider is negatively associated with competition in an IT innovation community.	Supported
H3. The entry rate of organizations that play the role of adopter is positively associated with legitimation in an IT innovation community.	Supported
H4. The entry rate of organizations that play the role of adopter is negatively associated with competition in an IT innovation community.	Supported

Chapter 6: Analysis and Results

This chapter provides additional analysis to address limitations and extend the results of the preliminary study. First, the issue of relying on a single discourse source (*Computerworld*) is addressed by adding more outlets to build a richer dataset, as multiple discourse sources are more likely to represent the ecology of CRM innovation community. Second, to address the issue of duplicate organizations, all duplicate organizations that had exited from the CRM innovation community due to mergers, acquisitions, and divestitures (MA&D) but appeared in the news articles after MA&D date were removed, as is typically done in traditional organizational ecology research (Amburgey et al., 1993; Hannan et al., 1995). Then, the validity of a density measure based on discourse data is verified by performing a sensitivity analysis with two additional examination windows (12-month and 18-month). Finally, scale-freeness, a network structure, is added to the ecological model to examine the dynamic network structure of the CRM innovation community, as described in section 3.4.

6.1. Multiple Data Sources

Concerning with the source of data, the preliminary study relies on a single source of discourse (*Computerworld*), and thus is potential subject to biases (e.g., lack of wide media coverage, one-sided perspective on CRM, and single audience) associated with that source (Gee, 1999; Hannan & Carroll, 1992; Holsti, 1969; Zucker, 1989; Zucker et al., 1998). Therefore, despite *Computerworld's* global reach and large circulation, and the importance of this historical period (1998-2007), more sources of discourse data should be added to build a richer dataset. The richer dataset

will have a wide spectrum of media coverage, synthesize different perspectives regarding CRM, and cover different audiences. Further, a richer dataset is more sufficient to represent the ecology of an innovation community, and more broadly an ecosystem. Overall, a richer dataset will help us to observe, examine, and understand the evolution of CRM and its associated community with good quality of data and measures.

6.1.1. Data collection

Additional news articles about CRM were collected from new outlets including *CIO magazine*, *New York Times*, *USA Today*, *Washington Post*, and *Wall Street Journal*. Unlike specialized venues such as press releases or academic journals that reflect the activities of one particular population/industry, newspapers and magazines capture the opinions and activities of a variety of engaged participants from multiple populations/industries. While the goal of collecting additional discourse data source is not to draw a sample that represents the entire CRM discourse worldwide, the outlets that were selected (and edited by different editors from different industries) did reach broad and diverse audiences and cover a large range of noteworthy IT, business, and general news that might have been related to CRM, to varying degrees. Combining with *Computerworld*, these additional outlets are expected to create a new dataset which has a wide spectrum of media coverage, synthesizes different perspectives of newspapers and magazines regarding CRM, and covers different audiences.

To create this new dataset, additional news articles were downloaded from the LexisNexis Academic database. In addition to its easy search and downloading

functions, LexisNexis Academic database covers a wide variety of newspapers and magazines including mainstream outlets such as *CIO magazine*, *New York Times*, *USA Today*, *Washington Post*, and *Wall Street Journal*. Merged *Computerworld* with these mainstream outlets, the new dataset is large and diverse enough to covers nearly the whole course of CRM's evolution, from its origin in the early 1990s, over its peak in popularity circa 2002, and through its more recent transformation. To be consistent with the preliminary study, the additional analysis will still focus on the ten-year observation window between 1998 and 2007.

Within LexisNexis, I specified each outlet and searched for the phrase "customer relationship management" in the subject headings that the database assigns to each article published between 1998 and 2007. Each article is assigned multiple subject headings. Each subject of an article carries a percentage value, which indicates the level of relevance of the subject to the article. The search of the news articles resulted in 594 articles whose subject headings include CRM with relevance scores. By using the automatic topic modeling process²⁷ in LexisNexis, 105 news articles (from *CIO magazine*, *New York Times*, *USA Today*, *Washington Post*, and *Wall Street Journal*) that carry 80% relevance score were considered for data processing. Articles with CRM subject below 80% were removed because the majority body of the articles only mentioned CRM in passing based on the content reading. Two coders then further read, coded, and analyzed the 105 articles independently and agreed to remove 11 articles that did not relate to the CRM

²⁷ For more details about LexisNexis's topic modeling see: https://www.lexisnexis.com/infopro/resource-centers/product_resource_centers/b/smartindexing/archive/2013/09/06/relevance-scores-50-99.aspx (accessed Aug 20, 2016)

software or technology. Together with the news articles collected from *Computerworld*, the final dataset has 286 articles for further processing and analysis (summarized in Table 6.1).

Table 6.1 Collection of Articles in Expanded Dataset

	Computerworld	New York Times	CIO Magazine	USA Today	Wall Street Journal	Washington Post
Original Dataset	192					
Expanded Dataset	192	44	19	12	10	9

6.1.2. Data processing

As detailed in Chapter 4, the additional news articles were processed in three steps. First, full text of the additional news articles were imported into ATLAS.ti (version 6.0.15). Then, organizations that have been involved in any aspect of producing and/or using CRM were identified. Last, the specific role that each organization played in the CRM innovation community was determined (see the list of community roles and examples in Table 6.2) based on the reading of the context where the organization was mentioned. Similar to the results in preliminary study, some organizations always play just one role. For example, Salesforce.com always played the role of a technology provider. Others may play more than one role, such as some universities not only researched on CRM but also adopted CRM for their own use.²⁸

²⁸ http://infolab.usc.edu/imsc/press/pdfs/ncr_computerworld_12=3=01.pdf (accessed Aug 20, 2016)

Table 6.2 Diverse Roles Organizations Play in the CRM Innovation Community from Expanded Dataset

Role	Sample Organization	Sample Sentence from Expanded Dataset
Academic Researcher	University of Southern California	NCR is working with the Integrated Media Systems Center at the University of Southern California (USC) in Los Angeles on a project called E-Motions. (<i>Computerworld</i> , 12/03/2001)
Adopter	Tipper Tie	Last fall, Tipper Tie began implementing Siebel Systems' standalone call center and sales-force CRM modules. (<i>CIO magazine</i> , 09/15/2000)
Consultant	KPMG Peat Marwick	Indeed, Joe Murray, a principal at KPMG Peat Marwick LLP's customer management practice in Irvine, Calif., says companies should think about providing financial incentives if they want users to adopt CRM systems. (<i>Computerworld</i> , 03/15/1999)
Industry Researcher	Gartner Group	The Gartner Group, a market research firm, estimated that half of all customer relationship management projects fail to achieve the goals they set out to accomplish. (<i>New York Times</i> , 10/01/2001)
Technology provider	SAP AG	SAP AG reportedly is nearing a deal to resell software made by a Nortel Networks Inc unit, in an effort to jump-start its offerings in the fast-growing market for customer relationship management (CRM) systems. (<i>Wall Street Journal</i> , 03/30/2000)

The dyadic relationships between organizations were also identified by following the coding approach detailed in Chapter 4 (Table 6.3). Using ATLAS.ti., two coders independently coded organizations, community roles, and relationships that appeared in the additional news articles. After coding each article, they compared their coding results, discussed, and reconciled the few (community role of 3 organizations and 7 relationships between two organizations) differences. ATLAS.ti was then used to merge the data from preliminary study with these coding results to create a new dataset. The expanded dataset includes 675 unique organizations, with 207 technology providers, 328 adopters, 56 consultants, 72 industry researchers, and

12 academic researchers being identified, respectively. Additionally, 381 *adoption* relationships, 118 *collaboration* relationships, 483 *competition* relationships, 128 *MA&D* relationships, and 146 *research* relationships were identified based on the 286 sample articles (Summarized in Table 6.4) . The new additions (the differences between original dataset and expanded dataset) in Table 6.4 show that there are a slight increase of organizations playing different community roles and their associated relationships. Such increase patterns suggest that there are no great differences between the original dataset and the expanded dataset. Therefore, the expanded dataset is sufficient to represent the ecology of the CRM innovation community with a wide coverage of various outlets for hypotheses testing.

Table 6.3 Types of Relationships between Organizations Co-Mentioned in the Same Paragraph from Expanded Dataset

Relation	Sample Organizations	Sample Sentence from Expanded Dataset
Adoption	GSA and Siebel Systems	The GSA also plans to use the Siebel system for other large projects, such as building federal courthouses and IRS service centers, ... (<i>Washington Post</i> , 08/12/2002)
Collaboration	Boss Group and Microsoft	Bill Hilf, Microsoft's director of technical platform strategy, said the company has a similar collaboration with another open-source firm, The Boss Group. (<i>Computerworld</i> , 02/14/2006)
Competition	Microsoft and Salesforce.com	Microsoft Corp is setting up showdown with Salesforce.com Inc in \$11 billion customer-relationship management, or CRM, software market. (<i>Wall Street Journal</i> , 12/07/2005)
Merger, Acquisition, & Divestiture (MA&D)	PeopleSoft and Vantive	PeopleSoft Inc. agreed yesterday to acquire the Vantive Corporation for stock valued at \$433 million, in a deal that adds Vantive's customer-focused services to PeopleSoft's E-business offerings. (<i>New York Times</i> , 10/12/1999)
Research	Forrester Research and Siebel Systems	"Companies want to buy by the drink, but Siebel offers them a nine-course meal," says Erin Kinikin of Forrester Research. (<i>USA Today</i> , 05/04/2004).

Table 6.4 Summary of Coding Results in Computerworld and Expanded Dataset

	Computerworld	Expanded Dataset	New Additions
Total Organizations Identified	567	675	108
Academic Researcher	7	12	5
Adopter	274	328	54
Consultant	47	56	9
Industry Researcher	64	72	8
Technology provider	175	207	32
Total Relationships Identified	1002	1256	254
Adoption	354	381	27
Collaboration	98	118	20
Competition	332	483	151
MA&D	81	128	47
Research	137	146	9

6.2. Issue of Duplicate Organizations

The second limitation has to do with the duplicate organizations mentioned in the news articles after MA&D date. For example, Siebel Systems was acquired by Oracle in 2005 Q3.²⁹ In traditional organizational ecology theory, it is assumed that Siebel Systems has exited from the innovation community and should not appear in any news articles after the MA&D date. However, duplicate organizations that had existed from the CRM innovation community after MA&D date were found in three news articles during the coding process (Listed in Table 6.5). As organizational ecology posits, duplicate organizations would affect the number of organizations in a population at a given time period, and thus the regression analysis results are subject to change. Therefore, by following the prior organizational ecology studies (Amburgey et al., 1993; Hannan et al., 1995), all duplicate organizations that had exited from the CRM innovation community but appeared in the news articles after MA&D date are removed for density calculation at that given time period. For example, if Siebel Systems appeared in a news article whose publication date (2007 Q1) was after Siebel Systems' MA&D date (2005Q3), Siebel Systems would not be counted as the number of organization (density) in 2007 Q1, since it had exited from the CRM innovation community.

²⁹ For more details about Siebel Systems acquisition see:
https://en.wikipedia.org/wiki/Siebel_Systems. (accessed Aug 12, 2016)

Table 6.5 Duplicate Organizations Appeared in Expanded Dataset after MA&D date

Organizations	MA&D Date	Appear after MA&D Date	Sample Sentence of Duplicate Organizations in Expanded Dataset after MA&D
Clarify	2000 Q1 ³⁰	2000 Q4	The center is being standardized around San Jose-based Clarify Inc.'s eFrontOffice customer relationship management (CRM) software, which will handle a "smorgasbord" of service activity, including customer support for the firm's tax business. (10/02/2000, <i>Computerworld</i>)
		2001Q3	Before it was acquired by Nortel, Clarify was considered the No. 2 customer-relation management supplier, behind Siebel. It has since suffered series of miscues and an exodus of senior executives. (08/27/2001, <i>USA Today</i>)
Siebel Systems	2005 Q3	2007 Q1	Bonhams' big competitors had chosen packages from SAP AG and Siebel Systems Inc., but Whitehead wouldn't go there. (02/21/2007, <i>Computerworld</i>)

³⁰ For more details about Clarify's acquisition see:
<http://www.prnewswire.co.uk/news-releases/nortel-networks-and-clarify-announce-meeting-date-for-clarify-stockholders-to-consider-nortel-networks-acquisition-155645025.html>. (accessed Aug 12, 2016)

6.3. Application of Density-Dependence Model to Innovation Communities

With respect to the data analysis, the application of organizational ecology and the density-dependence model at community level is effective in testing the hypotheses in the preliminary study. While the density-dependence model has long been used to test ecological theories, it has limitations such as primary focus on within-population level ecological effects (Hannan et al., 1995) and variable effectiveness with different types of data sources (Hannan & Carroll, 1992; Singh et al., 1993; Zucker, 1989; Zucker et al., 1998).

As organizational ecology theory holds, the application of density-dependence model requires that we describe the measure of participants, and specifically, the number of organizations in a population at any given time. Traditional organizational ecology studies have considered the ecology of a single population/industry (Amburgey et al., 1993; Baum & Mezias, 1992; Hannan et al., 1995; Swaminathan, 1995). In regard to the population/industry level analysis, since industries often have formal directories and rosters, organizational ecologists have used them as data sources to compile complete counts of the industry participants.

However, the composition of an innovation community makes it difficult to apply density-dependence model as traditional organizational ecology studies did. This is because populations of organizations in innovation communities are differentiated by the interests related to the innovations and the roles they play in the communities (Swanson & Ramiller, 1997; Wang & Ramiller, 2009) and thus not formally recognized as legal groups. As a result, populations of organizations in innovation communities do not have a clear definition of “membership”, not do they

typically have directories and rosters. Therefore, the traditional approach to applying density-dependence model with directory and roster data can not be used to study the ecology of an innovation community. Yet, understanding the community evolution requires us to consider the dynamics of multiple populations involved in an innovation community, as detailed in Chapter 3.

One solution to the lack of complete directories or rosters needed to study the evolution of CRM innovation community derives from the fact that most organizations involved in an innovation community, despite the different populations they belong to, engage in a discourse, as they comprehend, adopt, and develop an innovation (Swanson & Ramiller, 1997; Wang & Ramiller, 2009). Organizations from different populations in an innovation community engage in to affect the shape of the innovation, and they simultaneously attempt to agree on a common sense of such innovation. The common sense of an innovation is negotiated and shaped through discourse over time (Phillips & Hardy, 2002; Swanson & Ramiller, 1997). Hence, discourse can serve as the basis for observing participation of organizations in a multi-population innovation community (refer back to Section 4.1.1 for reasoning and more details).

However, unlike data of directories and rosters, discourse data is a sample of activities that must be processed to create measures and/or data about innovation community participants (Gee, 1999; Phillips & Hardy, 2002). As a sample of activities, discourse data is unlikely to capture all the activities of organizations involved in producing and/or using CRM worldwide at any given time period. Therefore, discourse data has limitations on multiple data sources, time window, etc

(Gee, 1999; Green, 2004; Holsti, 1969; Phillips & Hardy, 2002; Suddaby & Greenwood, 2005), which may bias the data and the analysis results. The issue of multiple data sources in this study has to do with the wide media coverage, different perspectives regarding CRM, and the coverage of different audiences. The issue of time window in this study is about why and how to measure the presence of organizations in an innovation community based on discourse data at a given time period. With respect to the problem of multiple data sources, a possible approach and solution has been proposed to address the issue in Section 6.1. The issue of time window with discourse data will be explained, detailed, and addressed here.

In organizational ecology (Hannan et al., 1995; Hannan & Freeman, 1993), the number of organizations (density) is used to capture two ecological processes (legitimation and competition) in the density-dependence model. The two ecological processes further restrict the number of organizations that enters a population (entry rate) and thus affects the dynamics of a population. Therefore, the measure of organization presence in a population is the foundation of the density-dependence model.

In traditional organizational ecology studies, it is feasible to define when an organization leaves a population, as it is usually reflected in the data sources such as directories, rosters, and *Red Book* (Baum & Mezias, 1992; Hannan et al., 1995). The density-dependence model explains the population dynamics well, as the presence of each organization is clear at any given time in the data source. However, analyzing with discourse data (news articles), it is difficult to determine when an organization leaves a population, and thus the number of organizations (density) in a population is

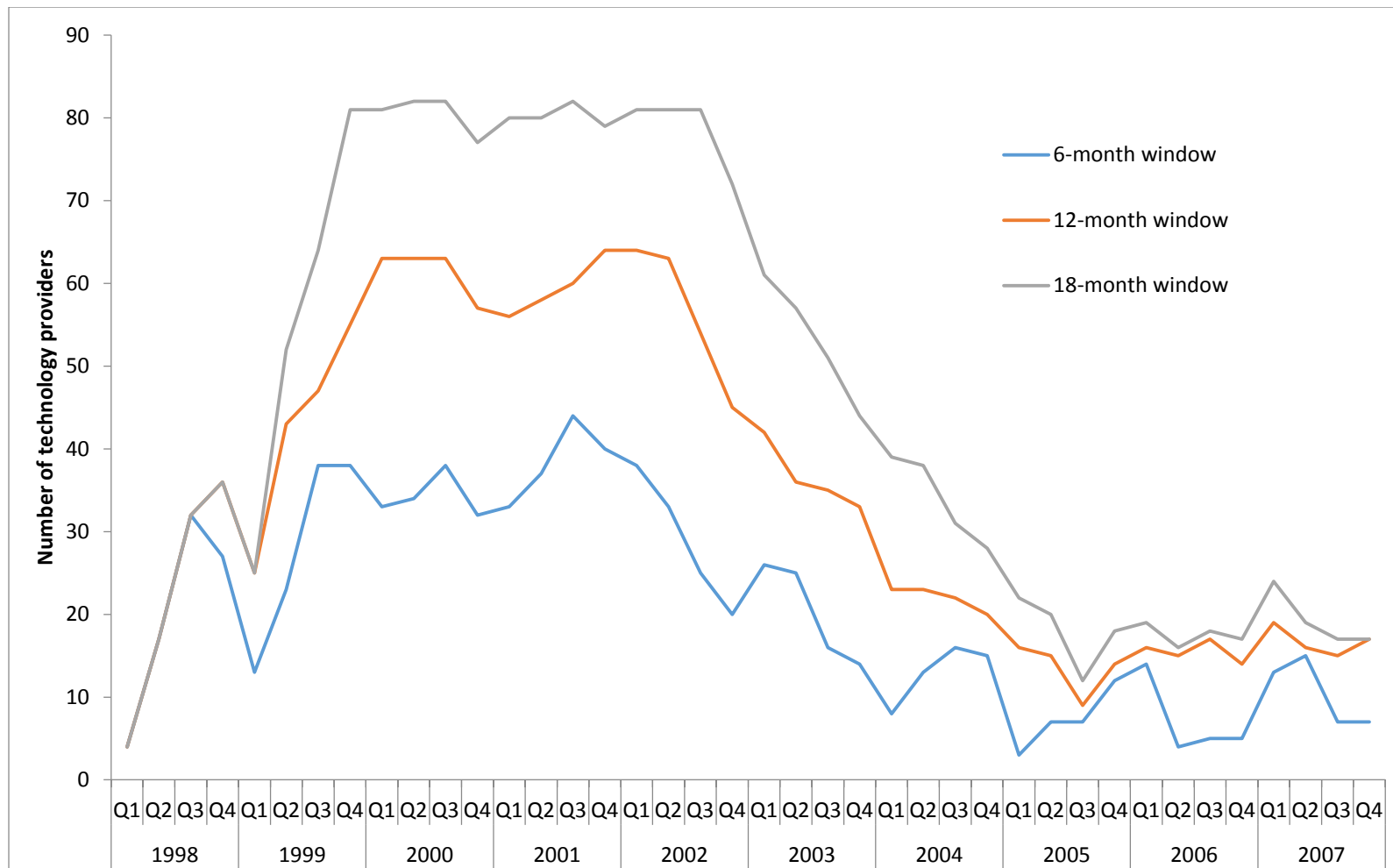
difficult to determine. For example, on one hand, if an organization does not appear in the discourse within a 6-month time period but appears later, then a measure based on a 6-month window will undercount the number of organizations present in the population. On the other hand, if the observation window is set for more than 6 month and there are more organizations appearing within the observation window, the number of organizations may be over-counted. In both situations, the application of density-dependence model to innovation communities may be affected.

To address this issue, a sensitivity analysis is considered to test the robustness of the results in the preliminary study. Besides the 6-month window, a 12-month window and an 18-month window are considered for additional analysis. The additional analysis uses a 12-month window and an 18-month window because the size of the window is related to the whole time period (1998-2007) and the temporal granularity of the discourse dataset. For dataset with short timescales, short windows are appropriate, whereas dataset with long timescales require longer observation windows for the measures to be able to capture changes. Short time windows lead to irregular trends in the estimates of the measure, while long time windows smooth out the trends (Helton et al., 2006). In addition, the shorter the time window is, the less accurate the estimate of the measures becomes (Chatterjee & Hadi, 2009). Therefore, given that the whole dataset covers 120 months (1998-2007) in this study, the 3-month window is dropped out because the observation window is short and likely to fail to capture the dynamic changes over time in the innovation community. Also, the maximum size of the observation window is limited to 18 months. Since there is no golden rule to define the maximum size of the observation window (Chatterjee &

Hadi, 2009), the size of the observation window is usually based on the length of the time dummy variable (two year in this study) which is used to control for and assesses the dynamic changes over time in the environment (Carroll et al., 1993; Carroll & Swaminathan, 1992). Alternatively, the size of the observation window can be set so that it captures only a small portion of the overall time period in a particular study (Levine & Renelt, 1992). Therefore, in this study, for example, an 18 month-window is long enough to observe the trends of populations' evolution based on the 10 year observation period and is likely to capture the dynamics of the innovation community.

With regard to the counts of the number of organizations in a population within a given observation window, if a technology provider had not been mentioned in any article over 12 and/or 18 months, it was assumed to have exited the community. In this way, the number of technology providers still assumed to be in the community each quarter was counted as the density of technology providers. For adopters, because it is unusual for any news agency to report adoption continuously and reporting abandonment of CRM software is even rarer, adopters were assumed not to leave the community. Therefore, the sensitivity analysis does not consider the absence of adopter. The density of adopters in any observation window is the number of adopters recorded cumulatively from quarter to quarter, which follows a classic S-shaped adoption curve (Rogers, 2003). The number of technology providers (density) presenting in 1998-2007 within different observation window is shown in Figure 6.1.

Figure 6.1 Number of Technology Providers Presenting in 1998-2007 within Different Observation Windows



6.4. Scale-free Measure

In addition to the participation of technology providers and adopters that contribute to shaping the ecology of an innovation community, the dynamic community structure matters for the development of the innovation community as well. This is because the structure of an innovation community can be represented as a network structure formed by various inter-organizational relationships within and among organizations. As detailed in Section 3.4, within an innovation community, a population with a network structure that can utilize the inter-organizational resources efficiently is able to accommodate more organizations in that population, which, in turn, supports more entries in the innovation community (*Hypothesis 5: the organizational entry rate of technology provider is positively associated with the scale-freeness of an innovation community*). Therefore, comparing populations (and ultimately innovation communities), network requires measures that capture the network ability to support efficient resource use. With regard to the measure of a network structure that can utilize resources efficiently, prior work has suggested that scale-free is a good candidate, because scale-free considers the function of highly-connected nodes in the network to support efficient resource use (Li et al., 2005; Sun & Wang, 2012).

The highly-connected nodes can also be seen in an innovation community. In an innovation community, populations of organizations engage in various activities to make sense of an innovation and are connected through different inter-organizational relationships arising from these activities (Baum & Rao, 2001; Hargrave & Van De Ven, 2006; Swanson & Ramiller, 1997; Van de Ven & Garud, 1993). The

connections among populations of organizations make them interdependent and form a network in an innovation community. As detailed in Section 3.3 and 3.4, an innovation community necessarily needs the early participation of technology providers to function well. Technology providers play an important role of spreading information such as the relevance of an innovation, the use of an innovation, and the development of an innovation. Community members are better able to access such information resources efficiently and comprehend the innovation and its sustained changes in time if they have made direct connections with technology providers. Different community members will then undertake different activities to take advantage of the information resources wisely. Therefore, technology providers are usually highly-connected with organizations playing other roles and establish various relationships in an innovation community.

With respect to scale-free network, Li et al. (2005) described that highly-connected nodes are the ones that have high degree centrality and betweenness centrality, and serve as the hubs in the network. They formulated a "scale-free metric" to characterize a network structure with highly-connected nodes in terms of scale-freeness. Briefly, g is a graph with edge-set ϵ , node i and node j have direct relationship in graph g . The degree (number of edges) at a node i is d_i and the degree (number of edges) at a node j is d_j . The level of scale-freeness of graph g is measured by $s(g) = \sum_{(i,j) \in \epsilon} d_i d_j$. The scale-freeness is maximized when high-degree nodes are connected to other high-degree nodes in the graph. The scale-freeness ratio is defined as $S(g) = s(g)/s_{max}$ where s_{max} is the maximum value of $s(h)$ and for h in the set of all graphs with an identical degree distribution to g . A network with low $S(g)$ is

"scale-rich;" and a network with $S(g)$ close to 1 is "scale-free." A network structure in high scale-freeness is expected to be better for information transmission and diffusion (Li et al., 2005).

As detailed above, technology providers are usually highly-connected with organizations that play other roles in an innovation community. For example, technology providers have direct adoption relationships with adopters, direct competition and MA&D relationships with other technology providers, and research relationships with both academic and industry researchers (Table 6.3). By following Li et al.'s (2005) approach, the scale-freeness network of CRM technology providers³¹ was calculated in each quarter by considering organizations that have direct relationships (e.g., adoption, competition, and research, MA&D) with the technology providers.

³¹ A step-by-step description of scale-freeness network of CRM technology provider with graphic illustrations is detailed in Appendices

6.5. Analytical Models

To examine the dynamics of both technology provider and adopter population in the CRM innovation community, the density-dependence model was employed with the expanded dataset to understand the ecological effects of competition and legitimation on organizational entry (Hannan et al., 1995). In the additional analysis, legitimation and competition for technology provider are not measured in the same way as the preliminary study did, as described in Section 6.3. Also, scale-freeness, a network structure measure, is added in the density-dependence model to examine the impact of dynamic community structure on organizations' entry.

Similar to the preliminary study, organizational entry rate is the dependent variable in the additional analysis. In the expanded dataset, the entry rate of organizations that play roles of technology provider and adopter was calculated separately. As the hypotheses suggest, the process of legitimation and competition for each group of organizations are likely to differ by the roles they play. Therefore, the entry rate of technology providers and adopters are also treated as two dependent variables in the additional analysis.

Specifically, for organizations that play the role of technology provider in CRM innovation community, the entry rate is measured by the number of technology providers that first appear in the CRM news articles in each quarter. Similarly, for organizations that play the role of adopter in CRM innovation community, the entry rate is measured by the number of adopters that first appear in the CRM news articles in each quarter. Last, for few organizations that may play more than one roles in

CRM innovation community, the entry rate is measured by such organizations playing certain roles that first appear in the CRM articles in a particular quarter.³²

There are three independent variables in the additional analysis: legitimation, competition, and scale-freeness. Legitimation and competition are both captured by the number of organizations (density) in a population (Hannan et al., 1995).

Legitimation is measured by density itself and competition is measured by the quadratic term of density. Scale-freeness is captured by the inter-organizational relationships directly associated with technology providers. The way of counting the number of organizations (density) based on a 12-month observation window and an 18-month observation window was detailed Section 6.3. The way of measuring scale-freeness network of technology providers was detailed in Section 6.4.

As described in Section 4.2, the organizational entry rate in the previous quarter and its quadratic term were included as control variables in all analytical models below (Carroll et al., 1993; Carroll & Swaminathan, 1992). Additionally, to control for potential impacts of various changes in the environment, five two-year dummy variables were also added in the observation period (1998-2007).

Not counting the baseline model (with the control variables only), three analytical models were constructed. Model 1 explains technology providers' entry rate using measures of legitimation and competition. The entry rate of technology providers in the previous quarter and its quadratic term were used as control variables. Specifically, Model 1 is constructed to test hypothesis 1 and hypothesis 2.

$$\lambda(t)_{TP} = \beta_1 n_{(t-1),TP} + \beta_2 n_{(t-1),TP}^2 + \beta_3 \lambda_{(t-1),TP} + \beta_4 \lambda_{(t-1),TP}^2 + \sum_{i=1}^4 \gamma_i y_i + \beta_0 \quad (1)$$

³² <http://www.computerworld.com/article/2567783/> (accessed July 8, 2016)

where $\lambda(t)_{TP}$ denotes the entry rate of technology providers in quarter t ; $n_{(t-1),TP}$ denotes the number of technology providers (density) in the community in the previous quarter $t-1$; $n_{(t-1),TP}^2$ denotes the quadric form of technology provider density in the community in the previous quarter $t-1$; $\lambda_{(t-1),TP}$ is the entry rate of technology providers in the previous quarter $t-1$; $\lambda_{(t-1),TP}^2$ is the quadric form of entry rate of technology providers in the previous quarter $t-1$; y_i is the dummy variable for the two-year period i (the base 2006-2007; y_1 is for 1998-1999; y_2 for 2000-2001; y_3 for 2002-2003; and y_4 for 2004-2005).

In Model 2, the term for the scale-freeness of the network encompassing technology providers and other organizations directly linked to the technology providers was added in the model, denoted by $sf_{(t-1),TP}$. The entry rate of technology providers in the previous quarter and its quadratic term were used as control variables. Specifically, Model 2 is constructed to test hypothesis 5.

$$\lambda(t)_{TP} = \beta_1 n_{(t-1),TP} + \beta_2 n_{(t-1),TP}^2 + \beta_3 \lambda_{(t-1),TP} + \beta_4 \lambda_{(t-1),TP}^2 + \beta_5 sf_{(t-1),TP} + \sum_{i=1}^4 \gamma_i y_i + \beta_0 \quad (2)$$

where $\lambda(t)_{TP}$ denotes the entry rate of technology providers in quarter t ; $n_{(t-1),TP}$ denotes the number of technology providers (density) in the community in the previous quarter $t-1$; $n_{(t-1),TP}^2$ denotes the quadric form of technology provider density in the community in the previous quarter $t-1$; $\lambda_{(t-1),TP}$ is the entry rate of technology providers in the previous quarter $t-1$; $\lambda_{(t-1),TP}^2$ is the quadric form of entry rate of technology providers in the previous quarter $t-1$; $sf_{(t-1),TP}$ denotes the scale-freeness network metric for technology providers; y_i is the dummy variable for the

two-year period i (the base 2006-2007; y_1 is for 1998-1999; y_2 for 2000-2001; y_3 for 2002-2003; and y_4 for 2004-2005).

Model 3 is based on adopter data and uses measures of legitimation and competition to explain the adopters' entry rate. The entry rate of adopters in the previous quarter and its quadratic term were used as control variables. Specifically, Model 3 is constructed to test hypothesis 3 and hypothesis 4

$$\lambda(t)_A = \beta_1 n_{(t-1),A} + \beta_2 n_{(t-1),A}^2 + \beta_3 \lambda_{(t-1),A} + \beta_4 \lambda_{(t-1),A}^2 + \sum_{i=1}^4 \gamma_i y_i + \beta_0 \quad (3)$$

where $\lambda(t)_A$ denotes the entry rate of adopters in quarter t ; $n_{(t-1),A}$ denotes the number of adopters (density) in the community in the previous quarter $t-1$; $n_{(t-1),A}^2$ denotes the quadric form of adopter density in the community in the previous quarter $t-1$; $\lambda_{(t-1),A}$ is the entry rate of adopters in the previous quarter $t-1$; $\lambda_{(t-1),A}^2$ is the quadric form of entry rate of adopters in the previous quarter $t-1$; y_i is the dummy variable for the two-year period i (the base 2006-2007; y_1 is for 1998-1999; y_2 for 2000-2001; y_3 for 2002-2003; and y_4 for 2004-2005).

6.6. Results

This section first briefly reviews the story of CRM innovation community evolution presented in Section 5.1 by describing some similar findings from the additional analysis. Then, I depict a few differences between the preliminary study and additional analysis. Third, I elaborate the possible reasons for these differences and explain how (and why) the additional analysis supports the overall story of CRM innovation community evolution detailed in Section 5.1. Last, using ecology theory and structure of the community network, I elaborate the basic model of technology providers and adopters entries into the CRM innovation community.

6.6.1. CRM innovation community evolution in expanded dataset

The time period (1998-2007) examined in the additional analysis is identical to the preliminary study. The most prominent organizations among the technology providers and adopters in the CRM innovation community are summarized in Table 6.6.³³ Similar to the results in the preliminary study between 1998 to 1999, IBM was the organization that most frequently appeared, with Oracle and SAP equally following up. During this initial time period, the CRM innovation community accommodated 76 technology providers, with IBM, Oracle, and SAP representing the top three most frequently mentioned organizations. In the adopter population, 69 adopters from diverse industries were mentioned in the sampled articles.

The prominence of these organizations is because, as a leading enterprise software adopted by most organizations in the late 1990s, ERP received great public attention in the CRM innovation community. Large ERP vendors such as IBM,

³³ Table 5.1 summarized the most prominent organizations in the populations of technology provider and adopter in the preliminary study

Oracle, and SAP rushed to adapt their offerings to meet the needs of the CRM innovation community. Nevertheless, despite the prominence of ERP vendors in the late 1990s, the CRM innovation community also included specifically focused CRM vendors such as Siebel Systems that was among the top 5 most frequently mentioned organizations in both sampled datasets during the period 1998-1999. Overall, IBM, Oracle and SAP were the most visible technology providers in the CRM innovation community as the suppliers of ERP systems.

After 2000, these dedicated CRM vendors rose in prominence in the CRM innovation community. It was this time period when Siebel Systems came to the public eye and CRM innovation community began to grow. The growth of CRM innovation community accelerated during the period 2000-2001 when more technology providers, adopters, and others joined the community. Specifically, the entry rate of technology providers reached its peak in 2000 and was followed by the twin peaks of adopters' entry rate in 2002, 2003 and the peak of discourse volumes as measured by paragraph count in 2002 (Figure 6.2).

In addition to those similar patterns as reported in Section 5.1, the expanded dataset suggested new insights. Siebel Systems appeared as the most frequently mentioned technology providers in both preliminary study and additional analysis between 2000 to 2005. The frequency and relative ranking of other organizations were different between the two analyses. For example, the frequency of SAP (14 in *Computerworld* and 18 in expanded dataset) and Oracle (8 in *Computerworld* and 18 in expanded dataset) is different during the period 1998-1999 (see Table 5.1 and Table 6.6). Also, there are some other ranking differences for SAP, Vantive, Clarify,

PeopleSoft and Microsoft during the period 2000-2001, period 2002-2003, and period 2004-2005. One possible reason for this variation is that discourse data is a sample of activities of organizations and is not a comprehensive record of all the organizations involved in the CRM innovation community worldwide. However, despite of such ranking differences, major CRM technology providers such as Siebel Systems, SAP, Oracle, IBM, Vantive, PeopleSoft, and Microsoft were identified in both preliminary study and additional analysis. Overall, there are some differences in related ranking of CRM technology providers between the preliminary study and the additional analysis. However, the set of technology providers identified in both cases is essentially the same, and therefore the results suggest that the population is well described in both preliminary study and additional analysis.

The next sub-section will explore the network structure of CRM innovation community with the expanded dataset and describe how different inter-organizational relationships shape the CRM innovation community.

Figure 6.2 Trajectories of CRM Discourse Volume and Entry Rates in Expanded Dataset 1998-2007

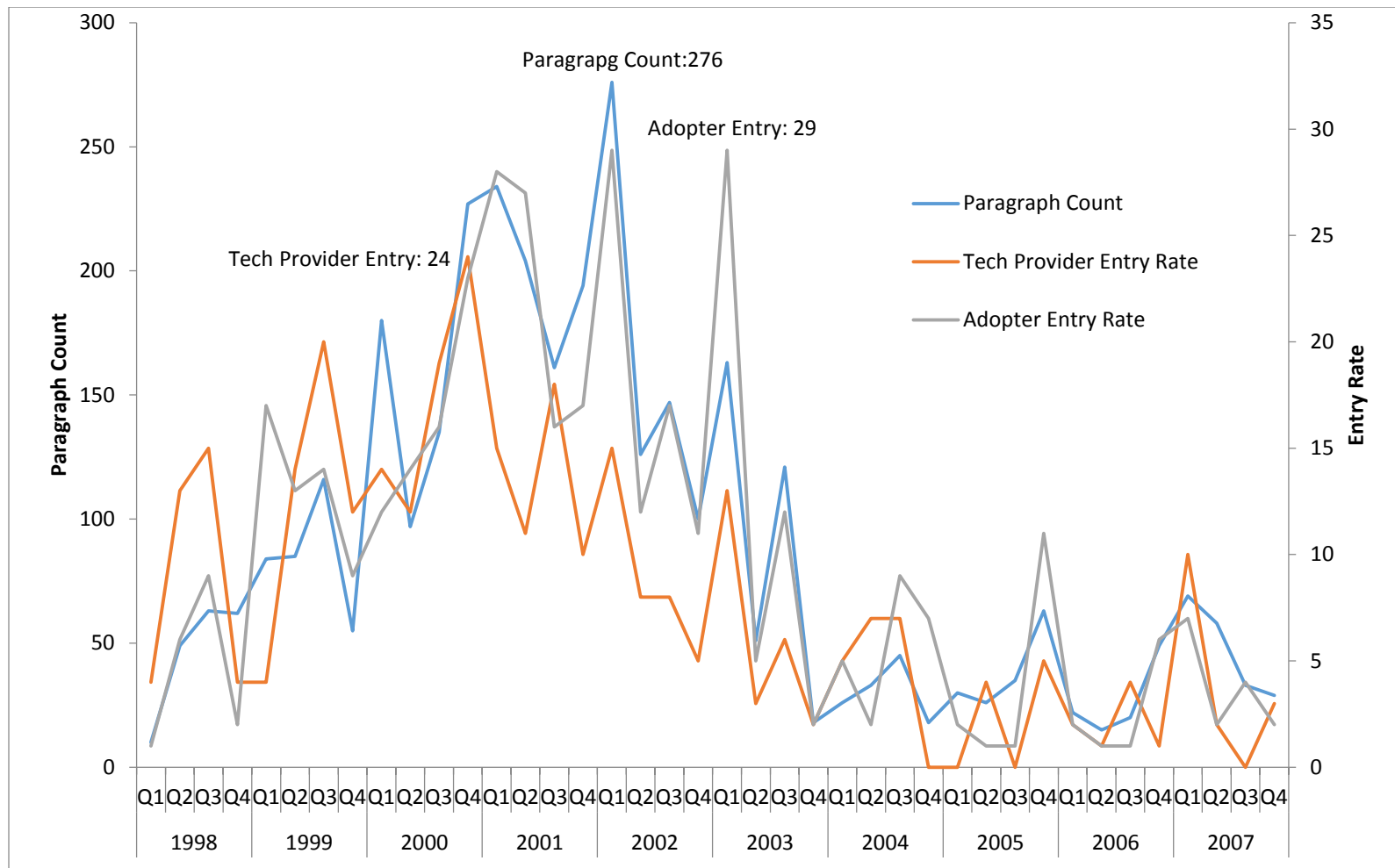


Table 6.6 Most Frequently Mentioned Tech Providers and Adopters in Expanded Dataset

	Tech Providers		Adopters	
	Organization	Freq.*	Organization	Freq.*
1998-1999	1 IBM	22	Peoples Energy	11
	2 Oracle	18	BankAmerica	10
	3 SAP	18	Delta	10
	4 Clarify	14	The Prudential Insurance s	9
	5 Siebel Systems	10	Volvo	9
	76 tech providers in this period		69 adopters in this period	
2000-2001	1 Siebel Systems	64	Harrah's Entertainment	35
	2 Clarify	34	Student Advantage	16
	3 PeopleSoft	31	Allstate	15
	4 SAP	29	TWA	15
	5 Oracle	24	Tipper Tie	13
	100 tech providers in this period		149 adopters in this period	
2002-2003	1 Siebel Systems	100	Dial Corp	12
	2 SAP	57	Mitsubishi	12
	3 Microsoft	36	Fleet Bank	10
	4 PeopleSoft	32	Charles Schwab	9
	5 Oracle	31	UNCB	9
	65 tech providers in this period		110 adopters in this period	
2004-2005	1 Siebel Systems	103	RBC Royal Bank	14
	2 Oracle	41	GSA	6
	3 IBM	21	General Motors	4
	4 SAP	21	Best Buy	3
	5 Salesforce	16	FedEx Corp	3
	25 tech providers in this period		36 adopters in this period	
2006-2007	1 Salesforce	47	Bonhams Ltd	6
	2 Microsoft	23	Heifer International	4
	3 SAP	16	Stratus Technologies Inc	4
	4 Oracle	12	Canada Post	2
	5 SugarCRM	5	Sprint	2
	20 tech providers in this period		25 adopters in this period	
	207 tech providers in 10 years		328 adopters in 10 years	

* The column shows the numbers of paragraphs from expanded dataset containing the corresponding organizations.

6.6.2. Network structure of CRM innovation community in expanded dataset

In developing and shaping CRM as a successful innovation, Siebel Systems has been one of the most important contributors, but it did not work alone. Rather, other technology providers and CRM innovation community members engaged in various activities to make sense of the innovation (Swanson & Ramiller, 1997). These activities allow organizations to form various inter-organizational relationships with each other and correspondingly enact a network that shapes the structure of the CRM innovation community. The structure of the CRM innovation community evolves, as organizations playing different roles in the CRM innovation community make different connections with each other over time (Baum & Rao, 2001; Freeman & Barley, 1990; Greve, 2002; Rao, 2002).

Therefore, in addition to general trends depicted in Section 6.6.1, the detailed dynamic community structure is also of great importance for understanding the evolution of CRM innovation community. This section explores the community network structure, reviews the findings reported in Section 5.2. , and explains the few differences between the preliminary study and additional analysis. Together with Section 5.2, this section provides us a more comprehensive picture of the evolution of CRM innovation community.

To explore the network structure of CRM innovation community, NodeXL was used for visualization. Figure 6.4 presents the community structure as shown in the expanded dataset in Quarter 1 of 2002 when the CRM innovation community had the most published discourse activities. NodeXL detected 12 clusters, showing the details of 10 in the boxes, and collapsing the other 2 in the lower right box. As

detailed in Section 5.1, strategic alliances, mergers and acquisitions are the primary ways which CRM technology providers develop, grow, and evolve in a relatively short time. CRM technology providers not only compete with each other, but also collaborate with each other in the CRM innovation community. The CRM innovation community evolved, as organizations grew and developed. Therefore, as in 2002 Q1 in *Computerworld*, the additional analysis identified many organizations that played different community roles forming different relationships in the CRM innovation community. For instance, major CRM technology providers such Microsoft and Oracle established both competitive and collaborative relationships, indicated by the cluster in the lower left box. The CRM innovation community also witnessed major CRM technology providers acquiring smaller CRM vendors to grow. To illustrate, PeopleSoft acquired smaller CRM vendor Vantive and Baan acquired Invensys and Aurum Software, as shown in the cluster in the upper left box and the cluster in the upper middle box, respectively. It is also worth noting that the mergers and acquisitions activities by the major CRM technology providers received the attention of industry researchers such as Garner, IDC, Hurwiz Group and Giga information Group, as they sought to understand and documented the business strategies made by these industry leaders.

In addition to those similar findings present in the preliminary study, the new network structure of CRM innovation community allows us to observe a more comprehensive picture of community evolution thanks to the richer dataset. First, we were able to see that the joint “adoption and collaboration” relationship is more prominent than the preliminary study suggested. For example, Siebel Systems was

adopted both by Fleet Bank and Xerox, and researched by Gartner. Meanwhile, consulting company McKinsey worked with Fleet Bank to make better use of the CRM technology provided by Siebel Systems, typically an indication of innovation community evolution suggested by organizing vision theory (Swanson & Ramiller, 1997).

Second, the inter-connections between the clusters are denser than those first appeared to be in both analyses. For example, together with Figure 5.2 (1998 Q3), Figure 5.3 (2002 Q1) presents a slight growth of the inter-connections between clusters over time in the preliminary study. In the additional analysis, the growth of inter-connection is even more prominent between the two time periods compared to the preliminary study. Indeed, there is a greater increase of inter-connections from 1998 Q3 to 2002 Q1 (Figure 6.3 and Figure 6.4) in the additional analysis. In NodeXL, the clustering function is used to detect groups which had densely connected organizations interacting with each other. The gray lines linking the clusters represent the edges that link the nodes in different clusters. Therefore, the presence of gray line suggests organizations not only build connections within the clusters but also build connections among clusters. The more gray lines are present, the more inter-connections between clusters exist. Overall, the growth of inter-connections between clusters in both analyses indicates the variation of relationships (e.g., competition and collaboration) formed by different organizations over time. As detailed in Section 3.3 and 3.4, inter-organizational relationships between organizations help them access resources, develop, and grow in the CRM innovation

community. The growth in number of organizations and the complexity of their inter-connections, in turn, reflects the development of CRM innovation community.

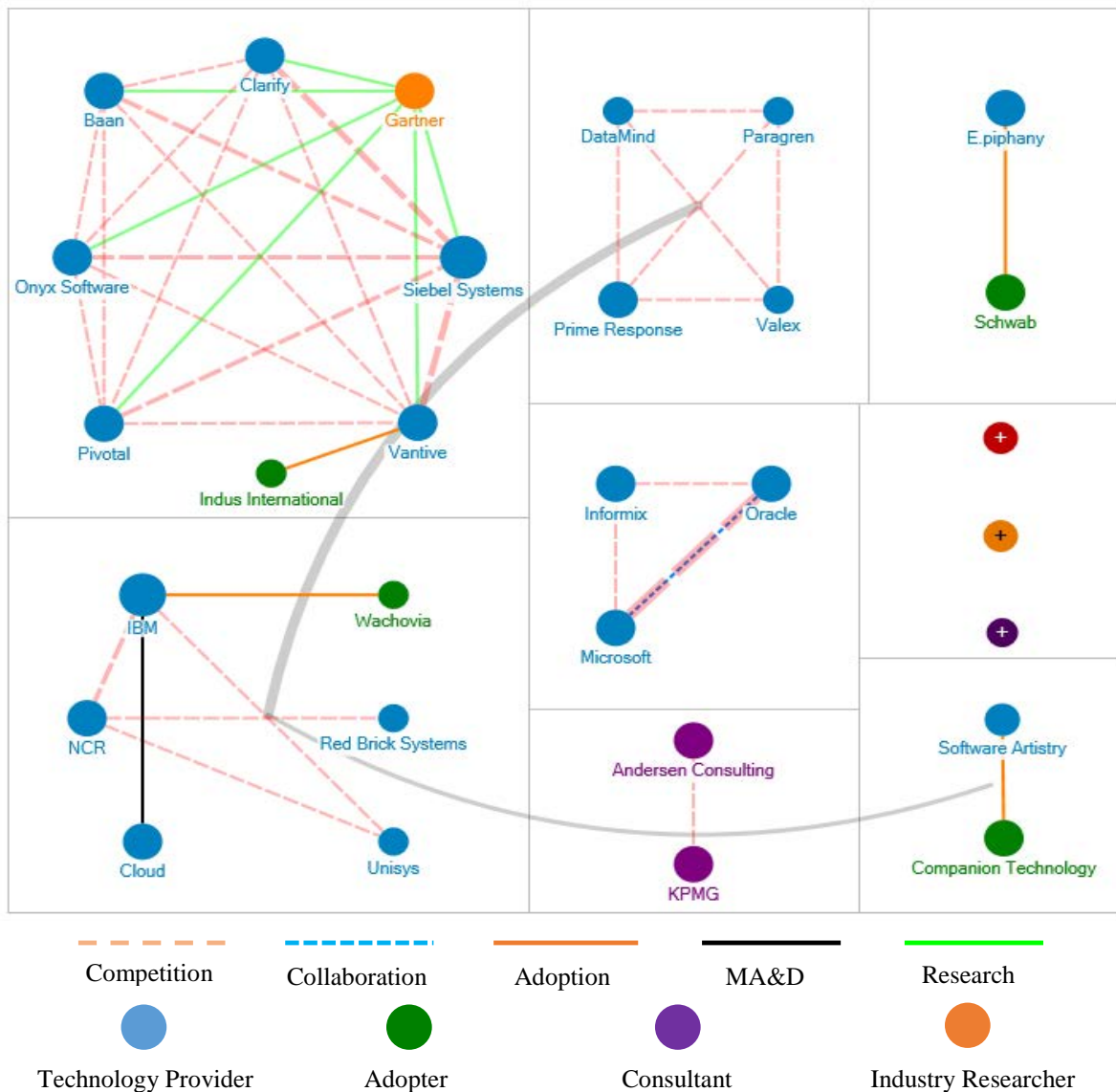
Third, it is worth noting that each major technology providers is in their “own” cluster, and each cluster is connected into the larger community network structure in a different way in 2002 Q1. For example, the cluster containing Siebel Systems which not only formed adoption relationships with Fleet Bank and Xerox and research relationship with Gartner, but also formed competition relationships with Oracle and SAP in other clusters. One possible reason for this change (compared to Figure 5.3) is that discourse data is a sample of activities of organizations and is not a comprehensive record of all the organizations involved in the CRM innovation community. Therefore, on one hand, when the expanded dataset (with more organizations and their associated relationships being identified) is used for NodeXL network structure visualization, the relevant organizations and their associated relationships become more prominent. On the other hand, the cluster function of NodeXL will automatically lay out a cluster in a box when nodes within the cluster have many connections in the expanded dataset.³⁴ Overall, the new analysis provides a more comprehensive view of the inter-connections between organizations and the evolution of CRM innovation community.

When the CRM innovation reached its peak popularity in 2002 as a result of the engagement of different community members (Swanson & Ramiller, 1997), the number of the technology providers also became steady. Large CRM technology providers survived and grew, whereas small CRM vendors were acquired and exited

³⁴ <http://snap.stanford.edu> (accessed Oct 01, 2016)

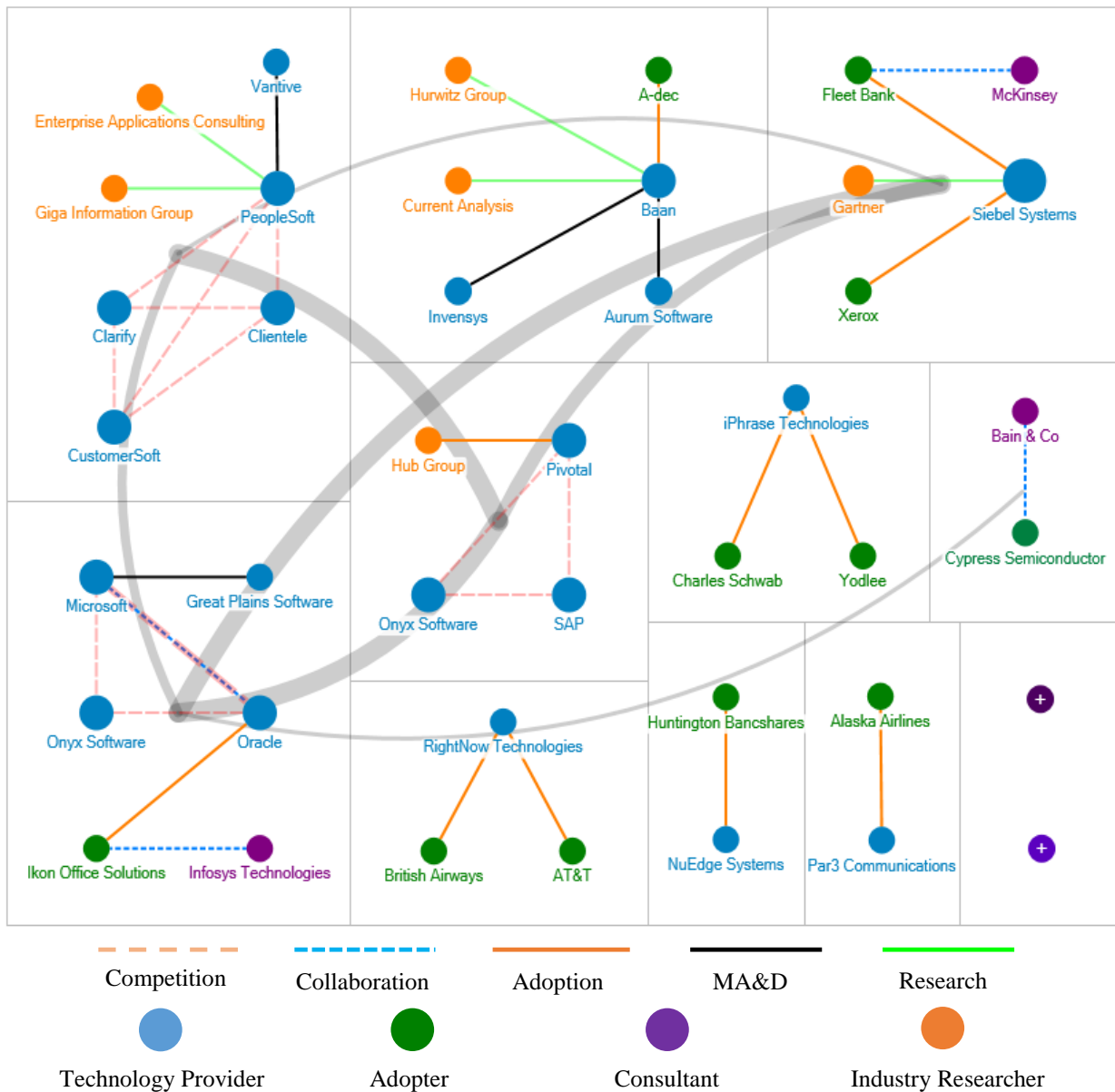
from the community. For those technology providers staying in the CRM innovation community, they struggled to keep their unique adopters by releasing CRM software package with new features, and meanwhile these existing technology providers had to face fierce competition with each other (see Figure 5.3 and Figure 6.4). There are many factors that affect how the technology provider and adopter population develop and grow. Section 6.6.1 describes the ecological changes of organizations and the CRM innovation community, and supports the findings as reported in Section 5.1. Based on a richer dataset, Section 6.6.2 depicts the community network structure which reflects such dynamic changes and provides us a more comprehensive view of the inter-connections between organizations and the evolution of CRM innovation community. But how do the composition of CRM innovation community and network structure shape its subsequent development? The results of regression analysis will reveal the half puzzle.

Figure 6.3 CRM Innovation Community Reported in Expanded Dataset in 1998 Q3



- Color of nodes represents the community role (Table 6.2); size of nodes represents the number of paragraphs where the organization was mentioned during this period: e.g., Red Brick Systems was mentioned in 1 paragraph and Siebel Systems was mentioned in 7 paragraphs.
- Color of edges represents the relationship (Table 6.3); thickness of edges represents the number of paragraphs where the pair of organizations with this relationship was mentioned during this period: e.g., the Informix-Microsoft competition relationship was mentioned in 1 paragraph and Siebel Systems-Vantive competition relationship was mentioned in 3 paragraphs.
- Gray lines linking the clusters in the figure represent the edges that link the nodes in different clusters. For example, the IBM-Prime Response competition relationship was mentioned in 1 paragraph.

Figure 6.4 CRM Innovation Community Reported in Expanded Dataset in 2002 Q1



- Color of nodes represents the community role (Table 6.2); size of nodes represents the number of paragraphs where the organization was mentioned during this period: e.g., Infosys Technologies was mentioned in 1 paragraph and Siebel Systems was in 15 paragraphs.
- Color of edges represents the relationship (Table 6.3); thickness of edges represents the number of paragraphs where the pair of organizations with this relationship was mentioned during this period: e.g., the PeopleSoft-Clarify competition relationship was mentioned in 1 paragraph and the Microsoft-Oracle competition relationship was mentioned in 2 paragraphs.
- Gray lines linking the clusters in the figure represent the edges that link the nodes in different clusters. For example, the Oracle-Siebel Systems competition relationship was mentioned in 4 paragraphs.

6.6.3. *The dynamics of CRM innovation community in expanded dataset*

Since the expanded dataset includes a sample of a wide spectrum of outlets about CRM, more organizations playing different roles were identified in the CRM innovation community. The descriptive statistics for the variables based on a 6-month window in expanded dataset are in Table 6.7. In the observation period (1998-2007), on average, about 8 technology providers and 10 adopters entered the CRM innovation community each quarter in the additional analysis, whereas about 6 technology providers and 7 adopters joined in the CRM innovation community each quarter in the preliminary study.

As detailed in Section 3.3, the number of organizations is used in density-dependence model to measure organizational density at a given time period (Hannan & Freeman, 1993). In the additional analysis, the CRM innovation community, on average, included about 21 technology providers (about 15 in the preliminary study) and 211 (about 165 in the preliminary study) adopters each quarter when the density measure is based on a 6-month observation window.

In the preliminary study, negative binominal regression was used for explaining the organizational entry rate, because the dependent variables are counts with data over-dispersed (Cameron & Trivedi, 1998). The expanded dataset covers a sample of a variety of outlets (including *Computerworld*) and the dependent variables are thus expected to be over-dispersed. Negative binominal regression was considered to be used to explain the organizational entry rate in the expanded dataset. Similar to the preliminary study detailed in Section 5.3, before doing this regression analysis, concerns on if negative binominal regression is suitable are addressed (conditional

variance exceeds the mean of both technology provider and adopter entry rates, Figure 6.5 and Table 6.8). In addition, issues of multicollinearity were tested for each regression model. The results suggest no serious problems of multicollinearity in the analysis (O'Brien, 2007).

Table 6.7 Descriptive Statistics of Main Variables in Expanded Dataset (6-month window)

	Mean	S.D.	1	2	3	4	5	6	7	8	9
Dependent Variables (t)											
1 Entry rate (tech provider)	8.00	6.33									
2 Entry rate (adopter)	10.10	8.43	0.69**								
Independent Variables (t-1)											
3 Density (tech provider)	20.75	12.5	0.79**	0.71**							
4 Density ² (tech provider)/1000	0.58	0.57	0.78**	0.68**	0.98**						
5 Density (adopter)	210.82	113.6	-0.59**	-0.29	-0.52**	-0.5**					
6 Density ² (adopter)/1000	57.03	40.52	-0.68**	-0.43**	-0.65**	-0.63**	0.98**				
Control Variables (t-1)											
7 Prior entry rate (tech provider)	7.93	6.41	0.59**	0.55**	0.85**	0.81**	-0.46**	-0.58**			
8 Prior entry rate ² /1000 (tech provider)	0.10	0.13	0.55**	0.52**	0.73**	0.72**	-0.43**	-0.54**	0.95**		
9 Prior entry rate (adopter)	10.05	8.48	0.46**	0.56**	0.76**	0.73**	-0.17	-0.32*	0.70**	0.62**	
10 Prior entry rate ² /1000 (adopter)	0.17	0.24	0.34*	0.47**	0.62**	0.62**	-0.1	-0.24	0.59**	0.53**	0.95**

t=1, 2, ..., 40 (1998Q1-2007Q4)

*: p<0.05; **: p<0.01; two-tailed tests

Period dummy variables are omitted.

Figure 6.5 Histograms of Technology Providers and Adopters' Entry Rate in Expanded Dataset

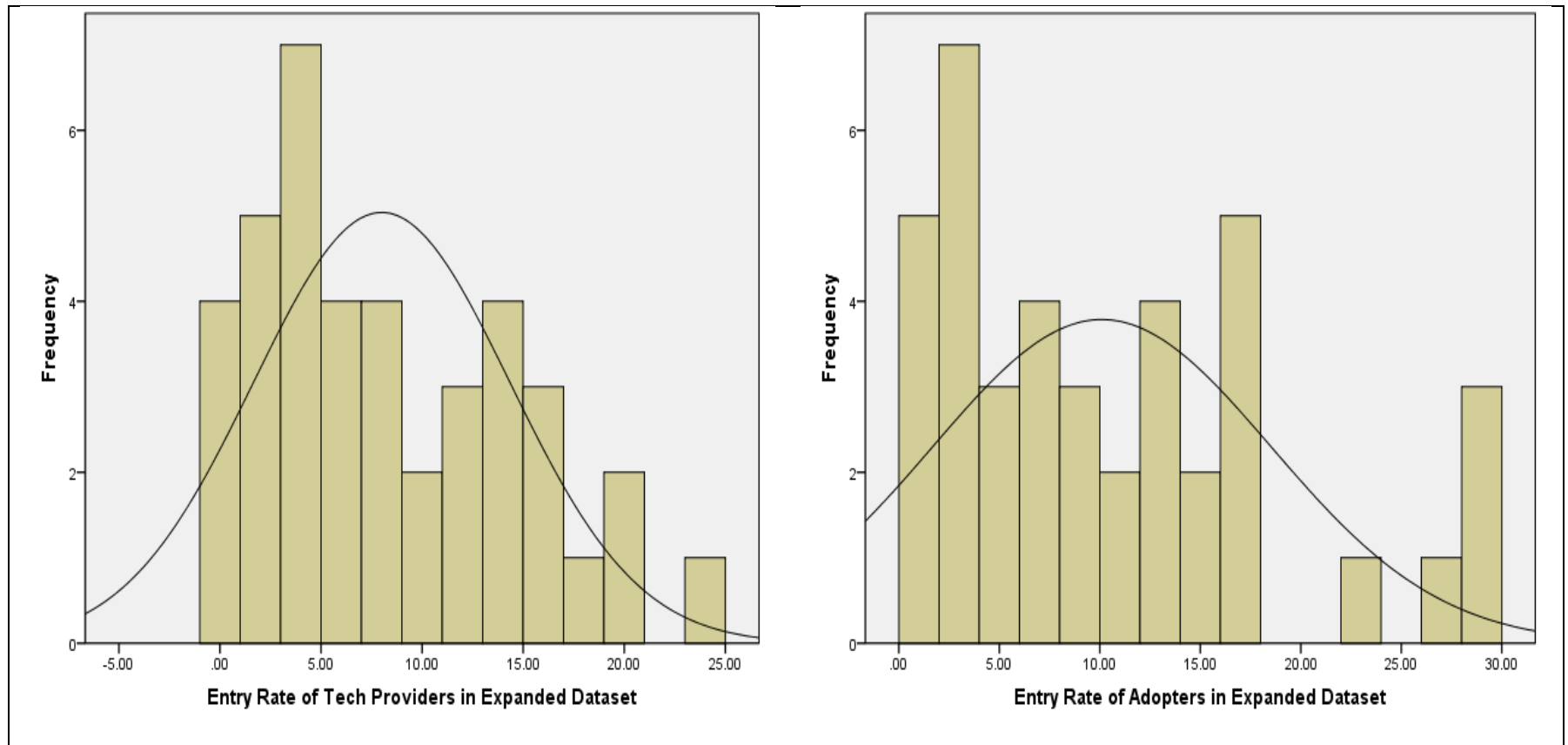


Table 6.8 Over-dispersion Test on Entry Rate of Technology Providers and Adopters in Expanded Dataset

Entry Rate of Technology Provider by Time Period			
Time Period	Mean of Entry rate	Number of Quarters	Conditional Variance
1998-1999	10.750	8	36.786
2000-2001	15.375	8	22.268
2002-2003	7.500	8	20.857
2004-2005	3.500	8	9.429
2006-2007	2.875	8	9.839
Entry Rate of Adopter by Time Period			
Time Period	Mean of Entry Rate	Number of Quarters	Conditional Variance
1998-1999	8.875	8	32.411
2000-2001	19.125	8	36.696
2002-2003	14.625	8	99.696
2004-2005	4.750	8	15.071
2006-2007	3.125	8	5.268

Model 1 (Table 6.9) considers and explains the entry rate of technology providers in the CRM innovation community when the density measure is calculated using a 6-month window. Pearson Chi-square is 8.68, suggesting the overall model is significant. Additionally, Akaike's Information Criterion (AIC) is 247.125 (positive), suggesting the overall model effectively explains the entry rate of technology providers. In Model 1, the prior entry rate of technology providers ($\beta = -0.28$; $p \leq 0.001$) and its quadric form ($\beta = 8.05$; $p \leq 0.001$), included as control variables, are significant. The legitimization measure (density of the technology providers) has a positive significant association with entry rate ($\beta = 0.24$; $p \leq 0.001$), whereas the competition measure (the quadratic form) has a negative significant association with entry rate ($\beta = -2.99$; $p \leq 0.01$). These results suggest that Hypotheses 1 and 2 are supported when tested with measures based on a 6-month observation window in the expanded dataset.

Model 2 (Table 6.9) is exclusively based on adopter data and explains the entry rate of adopters in the CRM innovation community. Pearson Chi-square is 12.15, indicating the overall model is significant. Additionally, Akaike's Information Criterion (AIC) is 269.172 (positive), suggesting the overall model effectively explains the entry rate of adopters. The results in this model are similar to those in the first model: significant positive effect of legitimization ($\beta = 0.03$; $p \leq 0.001$) and significant negative effect of competition ($\beta = -0.10$; $p \leq 0.01$) on adopters' entry rate. Regression results based on adopter data indicate that Hypotheses 3 and 4 are supported as well in the expanded dataset.

Together these models provide support for the hypotheses. And more importantly, in both sampled dataset, for organizations playing the role of technology provider and adopter in the CRM innovation community: legitimation has a positive effect on organizational entries, while competition has the opposite effect. In addition, data samples that excluded *Computerworld* are also examined and the regression shows that legitimation and competition do not have enough statistical power to affect the organizational entry rate of technology providers and adopters. Overall, the results suggest that there is no substantive change between the preliminary study (with *Computerworld*) and the additional analysis (with expanded dataset)

Table 6.9 Results of Negative Binominal Regression on Community Entry Rate in Expanded Dataset (6-month window)

	Dependent Variable (t)			
	Model 1 Entry rate (tech provider)		Model 2 Entry rate (adopter)	
Independent Variables (t-1)	Coefficient	S.E.	Coefficient	S.E.
Density (tech provider)	0.24 ***	0.05		
Density ² (tech provider)/1000	-2.99 **	0.80		
Density (adopter)			0.04 ***	0.01
Density ² (adopter)/1000			-0.10 **	0.03
Control Variables (t-1)				
Prior entry rate (tech provider)	-0.28 ***	0.06		
Prior entry rate ² /1000 (tech provider)	8.05 ***	1.88		
Prior entry rate (adopter)			-0.03	0.05
Prior entry rate ² /1000 (adopter)			0.03	1.34
Period (1998-1999)	0.35	0.28	1.32	1.09
Period (2000-2001)	0.40	0.32	0.71	1.08
Period (2002-2003)	-0.19	0.28	0.65	0.71
Period (2004-2005)	0.04	0.36	-0.08	0.48
Analytical model tolerance	0.0872		0.0876	
Akaike's Information Criterion (AIC)	247.125		269.172	
Pearson Chi-Square (df)	8.68**(31)		12.15**(31)	

t=1, 2, ..., 40 (1998Q1-2007Q4)

*: p<.05; **: p<.01; ***: p<.001 (one-tailed test)

6.6.4. Sensitivity analysis results

As described in Section 6.3, when analyzing with discourse data (news articles), it is difficult to determine at what time a technology provider leaves a population, and thus the number of technology providers (density) in the population is difficult to determine. To address this issue, a sensitivity analysis is considered to test the validity of density measure using different observation windows.

The descriptive statistics for the variables with a 6-month window, a 12-month window, and an 18-month window are in Tables 6.7, Table 6.10 and Table 6.11, respectively. In the observation period (1998-2007), on average, about 8.00 technology providers entered the CRM innovation community each quarter. As organizational ecology holds (Hannan & Freeman, 1993), the number of organizations is used in density-dependence model to measure organizational density. However, different observation windows result in different assessment of technology providers, which also affects the number of technology providers that are believed to be present in the CRM innovation community. Therefore, when a 6-month observation window is used, the CRM innovation community, on average, included about 21 technology providers each quarter. Similarly, when a 12-month window is used, the CRM innovation community, on average, included about 35 technology providers each quarter. Last, when an 18-month window is used, the CRM innovation community, on average, included about 46 technology providers. The results of sensitivity analysis are shown in Table 6.12.

Table 6.10 Descriptive Statistics of Main Variables in Expanded Dataset (12-month window)

	Mean	S.D.	1	2	3	4	5	6	7	8	9
Dependent Variables (t)											
1 Entry rate (tech provider)	8.00	6.33									
2 Entry rate (adopter)	10.10	8.43	0.69 **								
Independent Variables (t-1)											
3 Density (tech provider)	34.65	19.50	0.72 **	0.74 **							
4 Density ² (tech provider)/1000	1.57	1.48	0.71 **	0.73 **	0.98 **						
5 Density (adopter)	210.82	113.60	-0.59 **	-0.29	-0.40 **	-0.40 **					
6 Density ² (adopter)/1000	57.03	40.52	-0.68 **	-0.43 **	-0.57 **	-0.56 **	0.98 **				
Control Variables (t-1)											
7 Prior entry rate (tech provider)	7.93	6.41	0.59 **	0.55 **	0.78 **	0.76 **	-0.46 **	-0.58 **			
8 Prior entry rate ² /1000 (tech provider)	0.10	0.13	0.55 **	0.52 **	0.68 **	0.67 **	-0.43 **	-0.54 **	0.95 **		
9 Prior entry rate (adopter)	10.05	8.48	0.46 **	0.56 **	0.76 **	0.74 **	-0.17	-0.32 *	0.70 **	0.62 **	
10 Prior entry rate ² /1000 (adopter)	0.17	0.24	0.34 *	0.47 **	0.62 **	0.61 **	-0.10	-0.24	0.59 **	0.53 **	0.95 **

t=1, 2, ..., 40 (1998Q1-2007Q4)

*: p<0.05; **: p<0.01; two-tailed tests

Period dummy variables are omitted.

Table 6.11 Descriptive Statistics of Main Variables in Expanded Dataset (18-month window)

	Mean	S.D.	1	2	3	4	5	6	7	8	9
Dependent Variables (t)											
1 Entry rate (tech provider)	8.00	6.33									
2 Entry rate (adopter)	10.10	8.43	0.69 **								
Independent Variables (t-1)											
3 Density (tech provider)	45.93	27.33	0.69 **	0.74 **							
4 Density ² (tech provider)/1000	2.84	2.69	0.68 **	0.73 **	0.98 **						
5 Density (adopter)	210.82	113.60	-0.59 **	-0.29	-0.32 *	-0.33 *					
6 Density ² (adopter)/1000	57.03	40.52	-0.68 **	-0.43 **	-0.49 **	-0.51 **	0.98 **				
Control Variables (t-1)											
7 Prior entry rate (tech provider)	7.93	6.41	0.59 **	0.55 **	0.76 **	0.76 **	-0.46 **	-0.58 **			
8 Prior entry rate ² /1000 (tech provider)	0.10	0.13	0.55 **	0.52 **	0.67 **	0.68 **	-0.43 **	-0.54 **	0.95 **		
9 Prior entry rate (adopter)	10.05	8.48	0.46 **	0.56 **	0.79 **	0.77 **	-0.17	-0.32 *	0.70 **	0.62 **	
10 Prior entry rate ² /1000 (adopter)	0.17	0.24	0.34 *	0.47 **	0.65 **	0.65 **	-0.10	-0.24	0.59 **	0.53 **	0.95 **

t=1, 2, ..., 40 (1998Q1-2007Q4)

*: p<0.05; **: p<0.01; two-tailed tests

Period dummy variables are omitted.

Table 6.12 Results of Sensitivity Analysis with Negative Binominal Regression in Expanded Dataset

	Dependent Variable (t)					
	Model 1 Entry rate tech provider (t) 6-month		Model 2 Entry rate tech provider (t) 12-month		Model 3 Entry rate tech provider (t) 18-month	
Independent Variables (t-1)	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Density (tech provider)	0.24 ***	0.05	0.10 **	0.03	0.07 **	0.03
Density ² (tech provider)/1000	-2.99 **	0.80	-0.72 *	0.36	-0.40 *	0.24
Control Variables (t-1)						
Prior entry rate (tech provider)	-0.28 ***	0.06	-0.11 **	0.06	-0.10	0.06
Prior entry rate ² /1000 (tech provider)	8.05 ***	1.88	2.98	2.11	2.42	2.11
Period (1998-1999)	0.35	0.28	0.92 **	0.37	1.03 **	0.36
Period (2000-2001)	0.40	0.32	0.54	0.48	0.58	0.54
Period (2002-2003)	-0.19	0.28	-0.16	0.44	-0.25	0.50
Period (2004-2005)	0.04	0.36	0.11	0.40	0.16	0.43
Analytical model tolerance	0.0872		0.0894		0.0913	
Akaike's Information Criterion (AIC)	247.125		251.496		251.523	
Pearson Chi-Square (df)	8.68**(31)		11.98**(31)		12.50**(31)	

t=1, 2, ..., 40 (1998Q1-2007Q4)

*: p<.05; **: p<.01; ***: p<.001 (one-tailed test)

Model 1 considers and explains the entry rate of technology providers in the CRM innovation community when the density measure is calculated using a 6-month window. Pearson Chi-square is 8.68, suggesting the overall model is significant. Additionally, Akaike's Information Criterion (AIC) is 247.125 (positive), suggesting the overall model effectively explains the entry rate of technology providers. In Model 1, the prior entry rate of technology providers ($\beta = -0.28$; $p \leq 0.001$) and its quadric form ($\beta = 8.05$; $p \leq 0.001$), included as control variables, are significant. The legitimization measure (density of the technology providers) has a positive significant association with entry rate ($\beta = 0.24$; $p \leq 0.001$), whereas the competition measure (the quadratic form) has a negative significant association with entry rate ($\beta = -2.99$; $p \leq 0.01$). These results suggest that Hypotheses 1 and 2 are supported when tested with the measures based on a 6-month observation window.

In Model 2, the entry rate of technology providers in the CRM innovation community is explained by density-dependence model with a 12-month observation window. Pearson Chi-square is 11.98, suggesting the overall model is significant. Additionally, Akaike's Information Criterion (AIC) is 251.496 (positive), suggesting the overall model effectively explains the entry rate of technology providers. The prior entry rate of technology providers ($\beta = -0.11$; $p \leq 0.01$) and period dummy variable 1998-1999 ($\beta = 0.92$; $p \leq 0.01$), included as control variables, are significant. The legitimization measure (density of the technology providers) shows a positive significant relationship with entry rate ($\beta = 0.10$; $p \leq 0.01$), whereas the competition measure (the quadratic form) shows a negative significant relationship with entry rate ($\beta = -0.72$; $p \leq 0.05$). These results suggest that Hypotheses 1 and 2

are supported when tested with the measures based on a 12-month observation window.

Model 3 uses an 18-month window to examine the relationship between the entry rate of technology providers and the density (and its quadric form) of technology providers in the CRM innovation community. Pearson Chi-square is 12.50, suggesting the overall model is significant. Additionally, Akaike's Information Criterion (AIC) is 251.523 (positive), suggesting the overall model effectively explains the entry rate of technology providers. The period dummy variable 1998-1999, included as a control variable, is significant ($\beta = 1.03$; $p \leq 0.01$). The legitimization measure (density of the technology providers) shows a positive significant effect on entry rate ($\beta = 0.07$; $p \leq 0.01$), whereas the competition measure (the quadratic form) shows a negative significant effect on entry rate ($\beta = -0.40$; $p \leq 0.05$). These results suggest that Hypotheses 1 and 2 are supported as well when tested with the measures based on an 18-month observation window.

Together these models provide support for the hypotheses detailed in Section 3.3. For organizations playing the role of technology provider, despite the use of different observation windows (6-month, 12-month, and 18 month), the regression results are consistent: legitimization attracts organizational entries but competition deters them. Therefore, the sensitivity analysis shows that the results in the preliminary study are not affected by the observation window.

6.6.5. Effects of dynamic community structure on technology providers' entry

In the IT innovation world, it is common for two IT innovation communities have similar sizes during early years, but for one innovation to become the "next big thing," while the other just quietly disappears. Their different destinies suggest that the ecological forces (legitimation and competition) captured by the number of organizations in the density-dependence model may not be sufficient to fully explain the dynamic changes, as an innovation community evolves. What other factors might be in play? This sub-section reports the effects of efficient community structure on the entry rate of organizations that participate as technology providers in the CRM innovation community.

The descriptive statistics for all the main variables based on a 6-month window are in Table 6.13. In the observation period (1998-2007), on average, 8.00 technology providers and 10.10 adopters entered the CRM innovation community each quarter. The CRM innovation community, on average, included about 21 technology providers each quarter.

As detailed in Section 3.4, the inter-organizational relationships enact a network structure in an innovation community and function as an infrastructure that allows different organizations to access diverse inter-organizational resources. The utilization of inter-organizational resources by organizations leads to lower competition. A population with a network structure that can utilize the inter-organizational resources efficiently is able to accommodate more organizations in that population.

Comparing populations (and ultimately innovation communities), network requires measures that capture the network ability to support efficient resource use. With regard to the measure of a network structure that can utilize resources efficiently, prior work has suggested that scale-free is a good candidate, because scale-free considers the function of highly-connected nodes in the network to support efficient resource use (Li et al., 2005; Sun & Wang, 2012). The scale-freeness of the CRM technology provider network was calculated based on the inter-organizational relationships that are referenced in the sampled articles, which, on average, is 0.73 each quarter.

Similar to the procedures detailed in Section 6.6.3, negative binomial regression was employed (Cameron & Trivedi, 1998). The results of the negative binominal regressions including scale-freeness measure are shown in Table 6.14.

**Table 6.13 Descriptive Statistics of Main Variables including Scale-Freeness in Expanded Dataset
(6-month window)**

	Mean	S.D.	1	2	3	4	5	6	7	8	9	10
Dependent Variables (t)												
1 Entry rate (tech provider)	8.00	6.33										
2 Entry rate (adopter)	10.10	8.43	0.69**									
Independent Variables (t-1)												
3 Density (tech provider)	20.75	12.50	0.79**	0.71**								
4 Density ² (tech provider)/1000	0.58	0.57	0.78**	0.68**	0.98**							
5 Scale-freeness	0.73	0.13	0.73**	0.61**	0.75**	0.72**						
6 Density (adopter)	210.82	113.6	-0.59**	-0.29	-0.52**	-0.50*	-0.79**					
7 Density ² (adopter)/1000	57.03	40.52	-0.68**	-0.43**	-0.65**	-0.63**	-0.88**	0.98**				
Control Variables (t-1)												
8 Prior entry rate (tech provider)	7.93	6.41	0.59**	0.55**	0.85**	0.81**	0.63**	-0.46**	-0.58**			
9 Prior entry rate ² /1000 (tech provider)	0.10	0.13	0.55**	0.52**	0.73**	0.72**	0.56**	-0.43**	-0.54**	0.95**		
10 Prior entry rate (adopter)	10.05	8.48	0.46**	0.56**	0.76**	0.73**	0.53**	-0.17	-0.32*	0.70**	0.62**	
11 Prior entry rate ² /1000 (adopter)	0.17	0.24	0.34*	0.47**	0.62**	0.62**	0.45**	-0.1	-0.24	0.59**	0.53**	0.95**

t=1, 2, ..., 40 (1998Q1-2007Q4)

*: p<0.05; **: p<0.01; two-tailed tests

Period dummy variables are omitted.

Table 6.14 Results of Negative Binomial Regression Including Scale-freeness on Entry Rate in Expanded Dataset

	Dependent Variable (t)					
	Model 1 Entry rate tech provider (t) 6-month		Model 2 Entry rate tech provider (t) 12-month		Model 3 Entry rate tech provider (t) 18-month	
Independent Variables (t-1)	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Density (tech provider)	0.27 ***	0.04	0.13 ***	0.03	0.08 **	0.02
Density ² (tech provider)/1000	-3.22 ***	0.67	-1.00 **	0.33	-0.47 **	0.24
Scale-freeness	9.44 ***	1.98	8.46 **	2.97	7.74 **	3.04
Control Variables (t-1)						
Prior entry rate (tech provider)	-0.31 ***	0.05	-0.15 **	0.06	-0.12 **	0.06
Prior entry rate ² /1000 (tech provider)	9.51 ***	1.83	4.27 **	2.16	3.31	2.10
Period (1998-1999)	-2.52 ***	0.64	-1.94 **	1.00	-1.25	0.96
Period (2000-2001)	-3.04 ***	0.70	-2.87 **	1.19	-2.11 *	1.19
Period (2002-2003)	-2.54 ***	0.56	-2.59 **	0.93	-2.14 *	0.94
Period (2004-2005)	-0.85 *	0.40	-0.68	0.50	-0.81	0.54
Analytical model tolerance	0.0864		0.0885		0.0912	
Akaike's Information Criterion (AIC)	246.225		250.916		251.753	
Pearson Chi-Square (df)	6.44 ** (30)		10.27 ** (30)		11.45 ** (30)	

t=1, 2, ..., 40 (1998Q1-2007Q4)

*: p<.05; **: p<.01; ***: p<.001 (one-tailed test)

Model 1 considers and explains the ecological effects (legitimation and competition) and scale-freeness on entry rate of technology providers when the density measure is calculated using a 6-month window. Pearson Chi-square is 6.44, suggesting the overall model is significant. Additionally, Akaike's Information Criterion (AIC) is 246.225 (positive), suggesting the overall model effectively explains the entry rate of technology providers. In Model 1, the prior entry rate of technology providers ($\beta = -0.31$; $p \leq 0.001$) and its quadric form ($\beta = 9.51$; $p \leq 0.001$), included as control variables, are significant. Additionally, four period dummy variables are significant (period 1998-1999, $\beta = -2.52$; $p \leq 0.001$; period 2000-2001, $\beta = -3.04$; $p \leq 0.001$; period 2002-2003, $\beta = -2.54$; $p \leq 0.001$; Period 2004-2005, $\beta = -0.85$; $p \leq 0.05$). The legitimation measure (density of the technology providers) has a positive significant association with entry rate ($\beta = 0.27$; $p \leq 0.001$), whereas the competition measure (the quadratic form) has a negative significant association with entry rate ($\beta = -3.22$; $p \leq 0.001$). The scale-freeness, as a network efficiency measure, is positively associated with technology providers' entry into the CRM innovation community ($\beta = 9.44$; $p \leq 0.001$). These results suggest that Hypotheses 1, Hypothesis 2, and Hypothesis 5 are supported. Similar results (Model 2 and Model 3) were found for the legitimation, competition, and scale-freeness with a 12-month and an 18-month window, respectively.

In sum, legitimation attracts the organizational entries while competition hampers their entries into the CRM innovation community. The network measure, scale-freeness, has a positively significant relationship with the entry rate of organizations which seek to participate in the CRM innovation community as

technology providers. Together these models provide support for all the hypotheses detailed in Section 3.3 and 3.4.

Chapter 7: Conclusions and Discussions

This chapter first summarizes the findings and concludes the empirical results in this dissertation. Then, the limitations in this dissertation are elaborated and acknowledged. Third, the utilization and relative importance of ecological theory and network for understanding innovation community dynamics is explained. Fourth, theoretical contributions and possible future directions are discussed. Fifth, implications for practice (e.g., innovation community developers and technology innovators) are described. Last, the dissertation ends with final conclusions.

7.1. Summary of Findings and Empirical Conclusions

The field of IT innovation research is currently vast with numerous streams, traditions, and disciplines (Yoo et al., 2010). At the same time, it now considers innovation products and processes that are far more complex than in the past. Research on either supply side or demand side may not be sufficient to explain the dynamics of actors and activities. To understand this complex system, this dissertation considers the ecology framework. Ecology is a promising framework for the development of a holistic theory of IT innovation with sophisticated methods to explore the actors and activities surrounding an innovation within an innovation community. Specifically, by applying the ecology framework to innovation communities, this dissertation seeks to answer the research question: *How do the composition and structure within an IT innovation community shape its subsequent development.*

Since the framework of ecology considers various factors, actors, and activities that were traditionally treated separately in the IT innovation research,

research adopting this perspective enriches and advances our understanding of IT innovations and their associated communities. This dissertation is an early attempt to examine diverse actors and their activities in an IT innovation community based on discourse data. In collecting and processing the discourse data, samples of organizations playing different roles and their associated inter-organizational relationships were identified. Then, a preliminary study based on a single discourse data source (*Computerworld*) was conducted. Specifically, the preliminary study focused on technology providers (supply side) and adopters (demand side) and examined how the variations within the two primary populations in part affect the overall dynamics of the CRM innovation community. The frequency and relative ranking of technology providers in the observation period (1998-2007) present a general picture of major CRM technology providers and shed light on their primary business strategies for growth in the CRM innovation community. Then, the community network structures provide us a comprehensive view of the community by unfolding the various inter-organizational relationships formed by different organizations over time. Last, the application of density-dependence model to innovation community advances our understanding of population variation within an innovation community: the variation within populations captured by organizational entry rate (Rao & Singh, 1999) is affected by ecological forces, and in particular legitimation attracts organization entries, whereas competition has the opposite effects.

The analysis and results described in Chapter 6 addresses several limitations in the preliminary study and extends its results. The issue of relying on a single

discourse source (Computerworld) is addressed by adding more outlets to build a richer dataset, as multiple discourse sources are more likely to represent the ecology of CRM innovation community. Despite few relative ranking differences of technology providers between the preliminary study and additional analysis, the set of technology providers identified in both cases is essentially the same, and therefore the results suggest that the population of technology provider is well described in both preliminary study and additional analysis. Then, the new analysis on community network structure suggests that, in addition to an increased number of organizations playing different roles in the CRM innovation community over time, there is also a greater growth of inter-connections between clusters which include different types of organizations. The growth of inter-connections between clusters indicates the variations of relationships formed by different organizations, which allows organizations to access necessary resources, develop, and grow in the CRM innovation community over time. The growth in number of organizations and the complexity of their inter-connections, in turn, reflects the evolution of CRM innovation community. Last, the empirical results suggest that there is no substantive change between the preliminary study and additional analysis: legitimation attracts organizational entries, while competition deters them. Therefore, the ecology theory and its associated methods is effective to explain the variation within the two populations (technology provider and adopter) in the CRM innovation community when tested with measures based on a 6-month observation window.

In the second stage, the validity of density measure and application of density-dependence model to innovation community based on discourse data are verified by

performing a sensitivity analysis with two additional examination windows (12-month and 18-month). For organizations playing the role of technology provider, despite the use of different observation windows (6-month, 12-month, and 18-month), the empirical results are consistent. Therefore, the sensitivity analysis supports the conclusion that results in the preliminary study are not affected by the observation window. Further, by analyzing the community structure, this dissertation has demonstrated that scale-free network of organizations playing different roles, linked through diverse inter-organizational relationships, tended to attract technology companies to innovate with CRM by entering the CRM innovation community.

Overall, together with the preliminary study, the new analysis provides support for all hypotheses. First, the dynamics of innovation community could be explained in part by the variation of populations that compose such innovation community. Second, in addition to the ecological forces (legitimation and competition) that shapes the population variation over time, the variation of population could be understood and explained from a community network perspective. The scale-freeness network of organizations playing different roles, linked through diverse inter-organizational relationships allows organizations access different inter-organizational resources to develop and grow. A population with a network structure that can utilize the inter-organizational related resources efficiently is able to accommodate more organizations in that population.

7.2. Limitations

As any empirical study confined to its data and analysis, the study presented here has several limitations, as discussed below.

Regarding the data source, despite the large circulation of the prominent news outlets that were chosen in the additional analysis and the importance of this historical period, as a sample of activities, discourse data is unlikely to capture all the activities of organizations involved in producing and/or using CRM worldwide at any given time period. For example, as described in Section 5.1, Salesforce representing the cloud-based CRM technology providers dominated the CRM innovation community around 2006. However, because of the observation window size (1998-2007), it is unlikely to observe and examine the overall new wave of CRM technology transition. Second, although this study covers a wide variety of news outlets, these news outlets primarily documented organizations and their activities within North America. Therefore, future research is encouraged to include even more sources from other areas over longer time frames to examine the dynamics of innovation community worldwide.

Second, the limitations elaborated by the use of discourse data (i.e. public published articles) point to only one pool to examining the evolution of CRM innovation community, data from different sources such as press release and patent database may be analyzed separately to provide a more comprehensive picture of the evolution of CRM innovation community.

Last but not least, although CRM and its associated community had a colorful history with interesting twists and turns, which is highly desirable for theory building

and testing, it is a particular type of innovation. However, given the fast pace and high uncertainty nature of IT innovations, if we want to fully understand how to develop and make sense of IT innovations, it is not sufficient to study only successful IT innovations and their associated communities. Therefore, comparison with other innovations (e.g., emergent and failed innovations and their associated communities) should be in order.

With respect to the manual coding of qualitative data, this empirical study of sampled articles on CRM cannot completely eliminate threats to reliability. When analyzing with discourse data, ambiguity inevitably arises regarding the community roles that each organization plays in the CRM innovation community and inter-organizational relationships that two organizations form. Aware of this potential issue, two coders independently read all the articles with interactive and consensus-based coding strategies and phased coding to reconcile conflicts. For example, 675 organizations playing different community roles and 1256 different types of relationships were identified in the sample articles during the coding process. Two coders then compared their coding results, discussed, and reconciled the few (community role of 3 organizations and 7 relationships between two organizations) differences. The relatively smooth coding process gave us reasonable confidence in the primary findings and conclusions. However, multiple coders are encouraged to participate in the coding phase, as it is more likely to get the similar coding results in a relatively short time.

Further, the fast pace and uncertainty nature of IT innovations suggest that it is no longer sufficient to retrospectively study only successful innovations and their

associated innovation communities, but it is important to analyze contemporaneous data on different innovations and their associated innovation communities, including emergent and potentially failing ones, as they unfold. To accomplish research on multiple innovations using multiple data sources, manual qualitative analysis will soon reach its limit and therefore methods such as computational discourse analysis from other disciplines may be considered for examining multiple innovations and their associated communities.

In regard to data analysis, the approach of this study is effective in testing hypotheses (i.e., entry rates of key stakeholder groups). A sensitivity analysis regarding the density of technology provider has been conducted (with a 6-month window, a 12-month window, and an 18-month window) and showed a consistent results despite the use of different observation windows. However, just as any other organizational ecology studies, the density-dependent model was used to understand the innovation community dynamics by examining the ecological forces (legitimation and competition) in the innovation community. Both legitimation and competition were measured by the same variable (density), except that they were measured by the different functions of density. Neither legitimation nor competition was directly measured. This is a well-known limitation in all studies using the density-dependent model (Hannan et al., 1995). While some analytical approaches such as process research and case studies are effective to understand the ecological processes, such approaches could not assess the evolution of an innovation community itself, which is critical to the viability of an IT innovation (Baum & Amburgey, 2002; Baum & Rao, 2001; Rao, 2002; Swanson & Ramiller, 1997). As this dissertation seeks to

understand the innovation community dynamics by considering the activities of different populations involved in the innovation community, the benefits of applying the density-dependent model on the heterogeneous nature of the innovation community for IT innovations outweigh the shortcomings of the model itself. But future work should consider constructing measures that can directly explain the ecological forces (legitimation and competition) within a population, and ultimately within an innovation community.

With respect to the definition of adopter population, while adopters include firms from different industries that are beyond the boundary of a single population, they are competing for the same resources such as expert and consultants' time and knowledge and attention and services from technology providers. Moreover, in the context of an innovation community, despite of the diverse industries that adopters belong to, they work with technology providers to shape and co-develop the conceptual and material aspects of an innovation and play the role of interpreting the innovation and describing strategies for adopting it. In this regard, adopters in an innovation community can be considered as a population on the basis of their common roles, activities and the nature of them.

Second, although the traditional organizational ecology theory is effective to explain the dynamics of adopter population (i.e. legitimation attracts organizational entry rate, while competition deters organizational entry rate), there are alternative explanations for the dynamic changes of adopter population. For example, the traditional adoption curve with market saturation proposed by Rogers (2003) may account for the population dynamics of adopters. The adoption curve is considered as

a possible explanation for the dynamic changes of adopters because the curve suggests that drop off in new adopters is due to the possibility that everyone in the market has adopted the innovation, and in this regard, the market saturation is assumed 100% (Miller et al., 1999; Rogers, 2003). Another possible explanation to the drop off in new adopter is that, in the context of an innovation community, when an innovation is institutionalized and becomes a part of the routine and everyday practice, the wide spread acceptance of such innovation usually leads to less report of adoption by news agencies or media (Scott, 1995; Swanson & Ramiller, 1997). As a result, the population dynamics of adopters varies, as less mentions of adoption reported by news agencies or media. Overall, although organizational ecology theory is effective to explain the dynamics of adopter population, there are alternative explanations for the drop off in new adopters. Therefore, future studies considering and examining those possible explanations will complement and enrich our understanding on the dynamics of adopter population.

Third, this dissertation contains two major analysis: the preliminary study and the further analysis of expanded sample. The preliminary study uses *Computerworld* as a sample of discourse data, while the additional analysis includes multiple data sources such as *CIO magazine*, *New York Times*, *USA Today*, and *Washington Post*, and *Wall Street Journal*. The differences (types of articles) between preliminary study and the rest of data sources (excluding *Computerworld*) in expanded data sample raise concerns on the potential changes of coding that may affect the statistical power and regression analysis results. In the preliminary study, five types of community roles (175 technology providers, 274 adopters, 7 academic researchers, 64 industry

researchers, and 47 consultants) and five types of relationships (332 competition, 98 collaboration, 354 adoption, 81 MA&D, and 137 research) were identified in the sample articles. Using the same coding strategies, five types of community role (32 technology provider, 54 adopters, 5 academic researchers, 8 industry researchers, and 9 consultants) and five types of relationship (151 competition, 20 collaboration, 27 adoption, 47 MA&D, and 9 research) were identified in the expanded data sample excluding *Computerworld* (see Table 6.4). While the types of community role and relationships are essentially the same in both preliminary study and expanded sample excluding *Computerworld*, there are relative ranking differences in the community roles and relationships identified between the two data samples. For example, while organizations playing the role of technology provider and adopter are the two leading groups in both data sample, industry researcher is the third most prominent group in preliminary study and consultant is the third most prominent group in the expanded sample excluding *Computerworld*. Results of relative ranking differences were also found for the types of relationships identified between the two data samples.

One possible reason for this variation of community roles and relationships is that discourse data is a sample of activities of organizations and is not a comprehensive record of all the organizations involved in the CRM innovation community at any given time worldwide. However, despite of such ranking differences, major community roles and relationships were identified in both data samples. Overall, there are some differences in related ranking of community roles and relationships between the preliminary study and expanded data sample excluding *Computerworld*. However, the set of community roles and relationships identified in

both cases is essentially the same, and therefore the results suggest that the composition of innovation community is well described in both data sample. Further, this dissertation focuses on examining and explaining the population dynamics of technology provider and adopter, which are the two leading populations by ranking frequency in both data samples. Despite of the different types of articles between the two data samples, the composition of innovation community does not change. In both data samples, technology providers and adopters are the two leading groups and data of technology providers and adopters are the richest for analysis. Last, based on this limitation, future study that covers more data sources and longer time period is more sufficient to study the population dynamics (e.g., population dynamics beyond the technology provider and adopter) that determines the innovation community development and thus more likely to represent the ecology of an innovation community.

7.3. Innovation Community Dynamics: Ecology Theory and Network Structure

Current IT innovations involve products and processes that are far more complex than in the past (Yoo et al., 2010). If we are to fully understand the development and outcome of IT innovations, we first need to understand how the communities that support these IT innovations develop and grow (Swanson & Ramiller, 1997). In this regard, the recent rise of research on innovation communities (Sun & Wang, 2012; Wang & Ramiller, 2009), platforms (Cusumano, 2010), and ecosystems (Autio & Thomas, 2014) has opened up new ways of thinking about communities as ecological systems.

A lesson learned in prior work is that comprehensive research of innovation communities requires that we describe their overall dynamics and evolution. Innovation community dynamics occur when organizations that play different roles such as technology provider, adopter, consultant, and researcher join in or exit from an innovation community (Rao & Singh, 1999; Swanson & Ramiller, 1997). Since an innovation community is a heterogeneous inter-organizational community that encompasses diverse populations of organizations with different interests related to an innovation (Swanson & Ramiller, 1997), the overall dynamics and evolution of an innovation community is multifaceted. The first and foremost aspect is recognition of distinct populations playing different roles within an innovation community and examination of variations within each distinct population as a part of the innovation community dynamics. As reviewed in Chapter 2, new populations are formed when entrepreneurs develop new organization forms that use resources in novel ways. Just as variation in organizational forms in population ecology creates diversity (Rao &

Singh, 1999), variation among an innovation community's component gives rise to community dynamics. For example, the number of organizations playing different roles such as technology provider and adopter contributes to shaping population variations and how an innovation community develops over time. Therefore, examination of distinct role-based populations that compose an innovation community enriches our understanding of innovation community dynamics.

Specifically, community members play many significant roles in the development and shaping of the CRM innovation community. Technology providers take leadership early-on in interpreting the innovation with rationales ("know-what" and "know-why") and later on adopters come to dominate the innovation community as its focus shifted to the capabilities of how to use the innovation with strategies ("know-how")(Wang & Ramiller, 2009). The activities of technology providers and adopters in the CRM innovation community result in the co-development of conceptual and material aspects of the innovation (Baum & Rao, 2001; Hargrave & Van De Ven, 2006; Rao, 2002; Swanson & Ramiller, 1997; Van de Ven & Garud, 1993). The relative importance of technology providers' and adopters' participation suggests that a comprehensive study of their development is necessary. To describe the growth of each role-based population in the CRM innovation community, population ecology approach is promising. Population ecology posits that ecological forces (legitimation and competition) affect the variation within a population (Hannan & Freeman, 1977; Rao & Singh, 1999). Taking population ecology approach, this study thoroughly examines the variation within both the populations of technology providers and adopters as a part of the CRM innovation community and explains how

their participation shapes the CRM innovation over time. The results of this study reveal that variation within each distinct role-based population, in part, determines the innovation community dynamics.

Second, in the later stage of community evolution, when more and more organizations join in an innovation community, the selection processes occur, as the inter-organizational resources in the innovation community become a significant constraint. These selection processes are primarily shaped by inter-organizational relationships such as collaboration and competition between constituent populations of organizations (Astley, 1985; Rao, 2002). The inter-organizational relationships enact a network structure in an innovation community and function as an infrastructure that allows different organizations to access diverse inter-organizational resources. As detailed in section 3.4, the utilization of inter-organizational resources by organizations leads to lower competition. A population with a network structure that can utilize these resources efficiently is able to accommodate more organizations in that population. Population variation occurs when more and more organizations are able to enter a population (Rao & Singh, 1999). Therefore, in addition to community roles and ecological forces within each population, community network structures enacted by various inter-organizational relationships within and between populations are also of great importance to our understanding of innovation community dynamics. In this regard, this study has demonstrated that not only the variation within each distinct role-based population affect the overall innovation community dynamics, but also the network structures enacted by various inter-organizational relationships matter.

Overall, if we want to fully understand an innovation and the associated community, we need to describe how the innovation community develops and explain the dynamics of the innovation community. In sum, recognition of distinct role-based populations that are subject to their own ecological forces within an innovation community, selection processes shaped by inter-organizational relationships, and the overall community network structure are important factors which shape the innovation community evolution and dynamics.

7.4. Theoretical Contributions

This dissertation contributes to advancing ecology theory and its methods, especially in the context of innovation communities. First, the study leveraged organizational ecology research from the population level to the community level. As reviewed in Chapter 2, community ecologists have called for a comprehensive theory which considers and explains the composition and function of organizations that compose a community (Astley, 1985; DiMaggio, 1994; Greve, 2002; Korn & Baum, 1994; Rao, 2002). In this aspect, a wide variety of research work has begun to consider multiple populations that compose a community (Amburgey & Rao, 1996; Baum & Rao, 2001; Hannan, 2010; Rao, 2002; Rao & Singh, 1999) and argued that participation of multiple populations is important in developing and shaping a community (Astley & Fombrun, 1987; DiMaggio, 1994; Sun & Wang, 2012; Swanson & Ramiller, 1997; Wang & Ramiller, 2009). The complexity of IT innovations today presents an opportunity to advance ecology theory. Navigating this complexity requires new ways of understanding innovation activities based on novel product architecture and technological infrastructure that break traditional industry boundaries. Specifically, by taking the framework of ecology theory which considers both actors and activities within and among the industries and applying it to innovation communities, this study examines and explains the evolution of distinct role-based populations as a part of the innovation community, demonstrating the value of ecology theory in studying innovation community dynamics, and advancing our understanding of how innovations and associated communities develop.

Second, this study contributes to the innovation community literature by considering the heterogeneous nature of innovation communities. Despite some limitations of discourse data and analysis (Gee, 1999; Phillips & Hardy, 2002), this study takes advantage of the availability of public discourse to describe innovation community activity. By identifying and analyzing hundreds of organizations from different industries that are involved in the CRM innovation community, this study overcomes the known research challenge of organizations' heterogeneity. Drawing from prior innovation community work (Lynn et al., 1996; Sun & Wang, 2012; Swanson & Ramiller, 1997; Wang & Ramiller, 2009) and taking a further step, this study explains the heterogeneous nature of innovation community by examining the variation within different role-based populations as a part of the innovation community.

Third, by examining the ecological forces (legitimation and competition) based on the roles organizations play in the CRM innovation community, this study provides nuanced insights into the dynamic changes of each role-based population within the CRM innovation community. In particular, this study examines the variation in two primary populations (technology provider and adopter) and explains how the growth and activity of technology provider and adopter populations in the CRM innovation community helps to shape and make sense of the innovation over time. Additionally, unlike populations usually confined within industry boundaries, community roles may be flexible and feasible to examine separately within an innovation community. For example, organizations playing the role of technology provider can be considered as one population, while organizations playing the role of

adopter can be treated as another population. In this way, the ecological forces can be understood and examined among populations of organizations based on the role organizations play in an innovation community. This study has demonstrated that the evolution of an innovation community is subject to the variation within each distinct role-based population that composes the innovation community. Further, the ecological forces within each role-based population, in part, shape the overall innovation community dynamics. When seeking to understand the complexity of innovations and the associated communities, examination of distinct role-based populations in the innovation community is especially of great value in explaining innovation development phenomenon which crosses the boundaries of traditional industries.

Last but not least, in addition to interpretation of variation in different role-based populations that affects innovation community dynamics over time (Baum & Rao, 2001; Baum & Singh, 1994; Greve, 2002; Hunt & Aldrich, 1998; Rao & Singh, 1999), the study contributes to explaining how selection processes within a community affects development of the community in the later stage. The selection processes are shaped by inter-organizational relationships (e.g., competition and collaboration) between constituent populations of organizations (Rao, 2002). By introducing scale-freeness, a network efficiency measure, we are able to characterize the dynamic community structure enacted by inter-organizational relationships and test the claim that such a community structure leads to inter-organizational resource use and attracts new organizational entries in an innovation community.

In sum, this dissertation contributes to the community ecology literature by thoroughly examining the evolution and dynamics of an innovation community comprised of multiple inter-dependent populations. First, the study considers the heterogeneous nature of innovation community and demonstrates the relative importance of technology providers' and adopter's participation in developing and shaping an innovation within the innovation community. Second, this study examines the ecological forces within distinct role-based populations as a part of the innovation community. Last, the study unfolds the innovation community dynamics by explaining the selection processes shaped by various inter-organizational relationships in the later stage of community evolution.

7.5. Future Directions

Despite of the contributions and insights elaborated above, there are several aspects of innovation community dynamics that are beyond the scope of this study which future work should consider. First, this study examined the variations in two primary populations in the CRM innovation community and correspondingly explained their participation and contribution in making sense of the CRM innovation. However, as organizing vision theory suggests, the common sense of an innovation and the outcome of that innovation is the results of effort by all community members (Swanson & Ramiller, 1997). In other words, other community members such as consultants, academic researchers, and industry researchers also contribute to shaping the innovation and the associated community. Further, the current scope of many IT innovations has already transcended the traditional IT function to penetrate multiple business functions, and to reach beyond organizational and industry boundaries (Hannan, 2010; Mithas et al., 2013). Therefore, while the current analysis provides a view of community ecology and considers the supply and demand side in one study, a truly holistic analysis will need to take organizations playing other roles into consideration.

Second, although this study described and examined the heterogeneous nature of innovation community, it focused on an internal community dynamics perspective (i.e. variation within each population that is a part of an innovation community and inter-connection of these populations within a single community), without extending the results beyond the community boundaries. As Wang et al. (2013) suggested, the viability of a community is not only affected by its internal ecological forces, but also

affected by the large external ecological context. Therefore, future work should examine the effects of legitimation and competition among innovation communities, which complements this study focusing on an internal dynamics perspective. For example, do the ecological forces among innovation communities affect the development of these communities? How do the ecological forces among innovation communities affect the growth of such communities? Together with studies that take an internal dynamics perspective, future work on external dynamics perspective can provide us a comprehensive understanding of how to build viable innovation communities that support innovations and make sense of many innovations over time.

Third, this study tested and explained the effect of network structure on community dynamics by introducing scale-freeness, a network efficiency measure. While the empirical results support the conclusion that an innovation community with a network structure that has high scale-freeness tends to attract more organizations participating as technology providers, the scale-freeness measure merely considers and characterizes the function of highly-connected nodes (i.e. technology providers) and nodes that have direct relationships with highly-connected nodes in the network. Scale-freeness mainly examines and explains the effect of direct relationships between nodes and the “core” part of a network’s core-peripheral structure (Burt, 2009). It is less appropriate for describing the effect of indirect relationships and “peripheral structure” of a network (Chi et al., 2010; Li et al., 2005). In developing and shaping an innovation, technology providers do not work alone. Rather, other community members join in the innovation community and negotiate the content of the innovation in both conceptual and material aspects (Swanson & Ramiller, 1997).

The efforts of these community members result in many other inter-organizational relationships that technology providers are not directly involved in and hence is beyond the scope of scale-freeness. For example, adopters tend to collaborate with consultants when seeking to understand and make better use of a technology. Research covering this perspective would be able to incorporate the effects of indirect relationships and “peripheral structure” of a network and provide us a more comprehensive picture of community network structure on organizational entries. Therefore, future work may consider the participation of other community members (beyond technology providers and adopters) and relationships among them.

7.6. Implications for Practice

The framework and approach of ecological system benefit the practice of IT innovations and associated communities as well. For technology innovators, the ecological perspective offers them fresh insights. In shaping and developing the IT innovations, many new technologies deal with the vendor-analyst-adopter triangle relationship (Pollock & Williams, 2009). This dissertation reminds technology innovators of the relative importance of close collaboration with partners such as adopters, consultants, and researchers to make sustained technology improvements in the context of an innovation community. More importantly, technology innovators should realize that the community that supports an innovation is now much broader than just firm-based platforms and entities surrounding it. In this broader innovation community, legitimation, competition, and an efficient network of diverse relationships together shape the strategic decisions on innovation. Technology innovators should also be aware that the broader community usually offers more resources (e.g., skilled employees and adopters) than the industry analysts report. Therefore, knowing when and where to find what resources requires that technology innovators track closely the dynamics and evolution of an innovation community. For other community members who ponder whether to enter, stay in, or exit an innovation community, the ecological thinking can help them decide when to join in an innovation community for mutual benefits by establishing various inter-organizational relationships (e.g., collaboration and competition) with each other (Astley, 1985; Baum & Amburgey, 2002; Baum & Rao, 2001; Greve, 2002; Rao, 2002; Swanson & Ramiller, 1997).

Second, since an innovation community functions as a platform for shaping and developing an innovation, the innovation community provides new business opportunities and sources of business value for different organizations participating in it. For innovation community startups (i.e. developers), they need to be able to evaluate the opportunities and risks associated with developing and supporting an innovation community. This is because if an innovation community is not managed well, it can become inactive and a waste of resources (Butler, 2001) or even dissolve in a relatively short time, which results in failing to legitimize an innovation (Swanson & Ramiller, 1997; Zucker, 1989). In this regard, this study contributes to advancing innovation community developers' understanding about how and in what context innovation communities are likely to be viable and function well. The main findings in this study remind the innovation community developers to attend to community composition and heterogeneity. For example, an innovation community may need the participation of organizations playing specific roles to function well and correspondingly shape and make sense of an innovation.

Last but not least, research on ecological perspective and the associated approach can play an important role in understanding a variety of business domains in the future. In particular, Information Science, Information Systems and Business Practitioners which focus on the use and management of information and technology in a business context, is well positioned to study innovation communities. This dissertation is part of an effort to explain the dynamics and evolution of innovation community, explore the structure of innovation community, and contribute to the IS field by developing new theory of IT innovation. Finding in this study suggest that, in

addition to ecological forces that shape the development of an innovation community, inter-organizational relationships enact the structure of the innovation community and foster its growth. Both technology innovators and innovation community developers need to have a good understanding of the innovation community's ecological environment and various inter-organizational relationships formed by populations of organizations as a part of the innovation community. Last, for organizations playing different roles in an innovation community, this work suggests that they should not only pay attention to the ecological forces within each population, but also attach importance to the ecological forces beyond the population boundaries (Butler & Wang, 2012; Wang et al., 2013). Community members need to deal with the type of ecological force that matches the nature of their own populations. In sum, this dissertation highlights the relative importance of context to technology innovators, innovation community developers and other community members involved in the innovation community: both ecological forces and inter-organizational relationships play significant roles in shaping the innovation community dynamics and evolution. These elements should not be ignored when developing an innovation community.

7.7. Conclusions

As this dissertation concludes, there are many other ways that IS research can study the innovation communities. The complexity of IT innovations today challenges us to extend existing theories and models, and proposes new ones. Specifically, this study advances our understanding of ecology theory by extending it from population level to community level, which highlights the importance of both ecological forces and inter-organizational relationships between and within populations of organizations. Second, the ecological perspective and the associated approach in this study contribute to bridging the gaps between supply and demand, between development and diffusion, and between design and use. Ecology theory, as a new addition to the repertoire of theories on IT innovations, is especially constructive for bridging the divisions between various streams, traditions, and disciplines in the research on IT innovation communities (Wang & Ramiller, 2009) and/or even broader as ecosystems (Autio & Thomas, 2014). While the empirical results of the two studies provide a basis for extending the theory, future work taking the ecological approach is needed to better understand the factors for developing viable innovation communities and the value of innovation communities to different contexts. Indeed, this dissertation is a modest start and there is much to be done.

Appendices

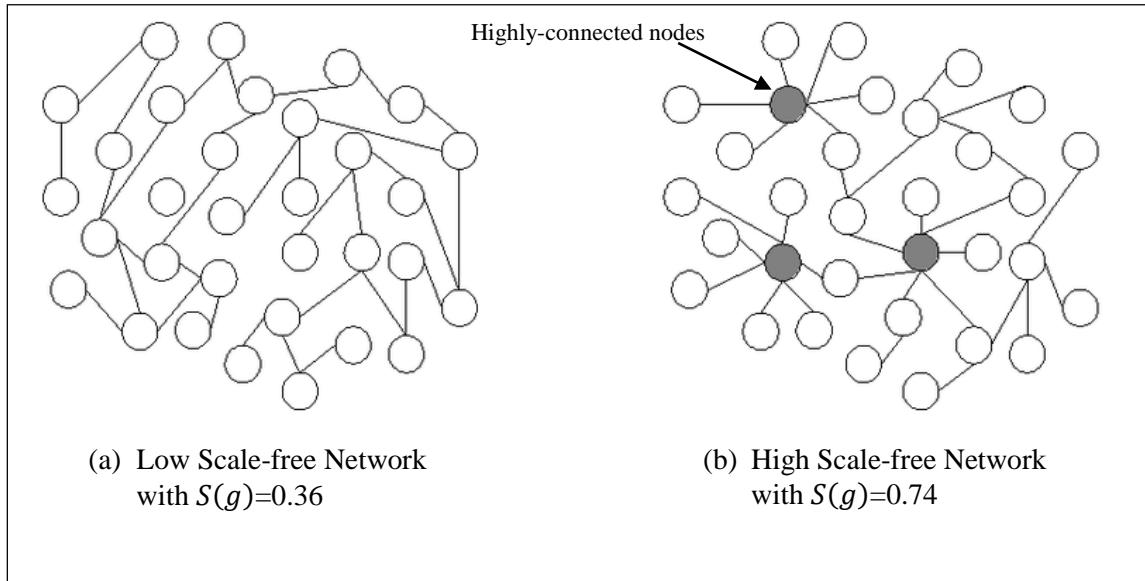
Calculation of Scale-free Measure

With respect to scale-free network, Li et al. (2005) described that highly-connected nodes are the ones that have high degree centrality and betweenness centrality, and serve as the hubs in the network. The term “scale-free” network was first coined by Barabási and Albert (1999) to describe the type of network that has a “heavy-tailed effect” following a pareto distribution or power law distribution. A scale-free network has nodes that are connected not randomly or evenly, but includes a few highly-connected nodes to connect other nodes in the network (Barabási, 2003). A network structure with high scale-freeness is expected to be better for information transmission and diffusion (Callaway et al., 2000; Cohen et al., 2000, 2001). They formulated a "scale-free metric" to characterize a network structure with highly-connected nodes in terms of scale-freeness. Briefly, g is a graph with edge-set ϵ , node i and node j have direct relationship in graph g . The degree (number of edges) at a node i is d_i and the degree (number of edges) at a node j is d_j . The level of scale-freeness of graph g is measured by $s(g) = \sum_{(i,j) \in \epsilon} d_i d_j$. The scale-freeness is maximized when high-degree nodes are connected to other high-degree nodes in the graph. The scale-freeness ratio is defined as $S(g) = s(g)/s_{max}$ where s_{max} is the maximum value of $s(h)$ and for h in the set of all graphs with an identical degree distribution to g . A network with low $S(g)$ is "scale-rich;" and a network with $S(g)$ close to 1 is "scale-free". Figure 8.1 illustrate two network structures³⁵ which have the

³⁵ Illustration of Network Structures is adapted from “Effective Web Crawling” by Castillo (2005).

same number of nodes and connections, one network with low Scale-freeness, and the other network with high Scale-freeness.

Figure 8.1 Illustration of Network Structures in Low and High Scale-freeness



As detailed in Section 3.4, technology providers are usually highly-connected with organizations that play other roles in an innovation community. For example, technology providers have direct adoption relationships with adopters, direct competition/MA&D relationships with other technology providers, and research relationships with both academic and industry researchers (Table 6.3). By following Li et al.'s (2005) approach, the scale-freeness of the network of CRM technology providers was calculated in each quarter by considering organizations that have direct relationships (e.g., adoption, competition, MA&D, and research) with the technology providers. Figure 8.2 presents the network structure of CRM technology provider which contains direct relationships (e.g., competition between Siebel Systems and Oracle, adoption between Siebel Systems and Student Advantage, and research between Siebel Systems and AMR Research) in 2000 Q3.

Figure 8.2 Network Structure of CRM Technology Provider with Direct Relationships in 2000 Q3

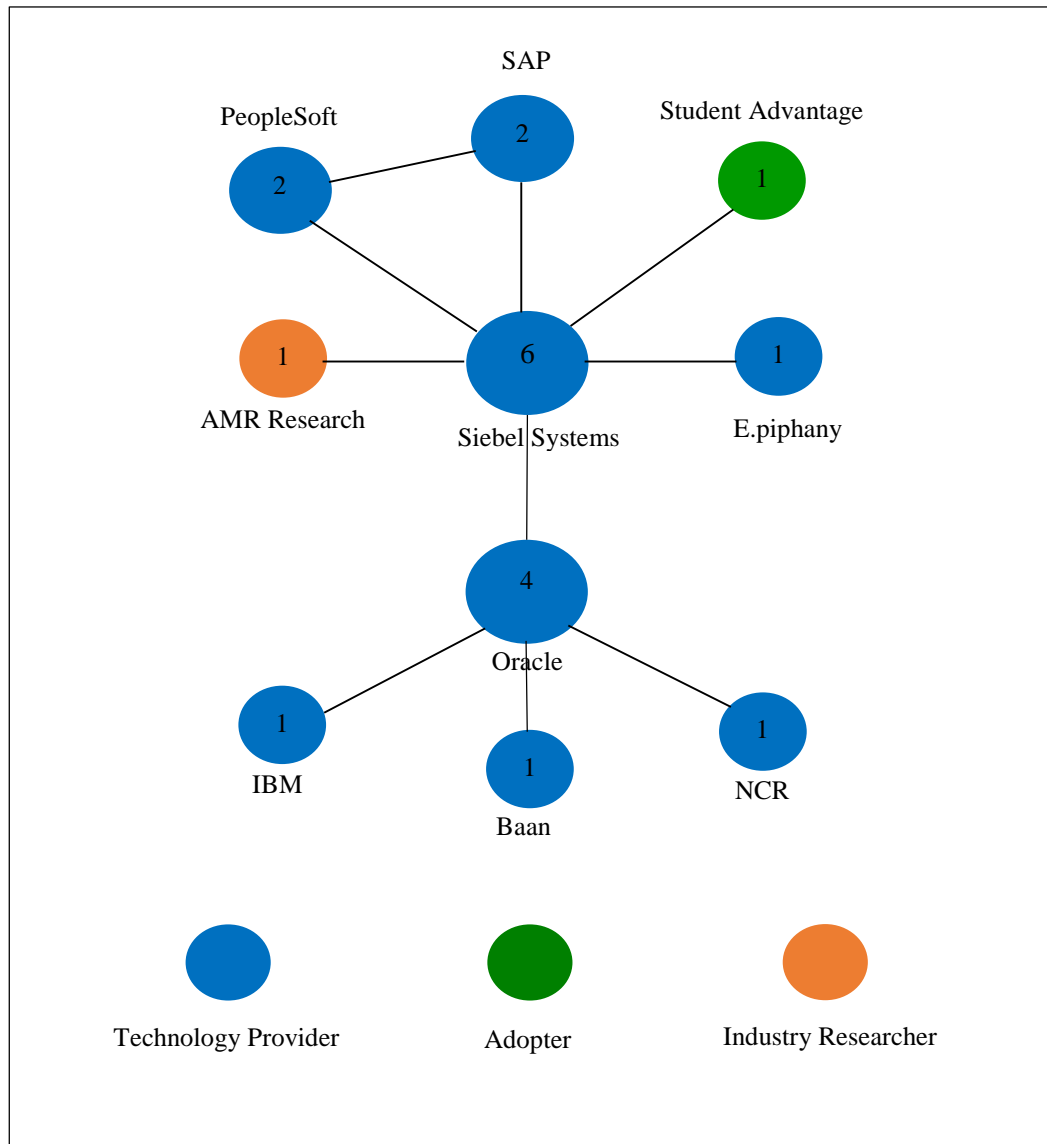


Table 8.1 summarizes a matrix table (top triangle) of nodes with direct relationships (and associated node degrees) in the network of CRM technology provider in 2000 Q3. According to Li et al. (2005), g is a graph with edge-set ϵ , node i and node j have direct relationship in graph g . The degree (number of edges) at a node i is d_i and the degree (number of edges) at a node j is d_j . For any two nodes that are directly connected in the network, the scale-free level is measured as $d_i d_j$. To illustrate, in the network of CRM technology provider (Figure 8.2), the scale-free level of two nodes (Siebel Systems and Oracle) that have direct connections is measured by the number of their edges: # of edges_{Siebel Systems} (6) * # of edges_{Oracle} (4) = 24. Correspondingly, the level of scale-freeness of graph g is measured by $s(g) = \sum_{(i,j) \in \epsilon} d_i d_j$ (Li et al., 2005). Therefore, by using the formula $s(g) = \sum_{(i,j) \in \epsilon} d_i d_j$, the level of scale-freeness of CRM technology provider network in 2000 Q3 is 84.

Table 8.1 Matrix of Scale-freeness Level of CRM Technology Provider Network in 2000 Q3

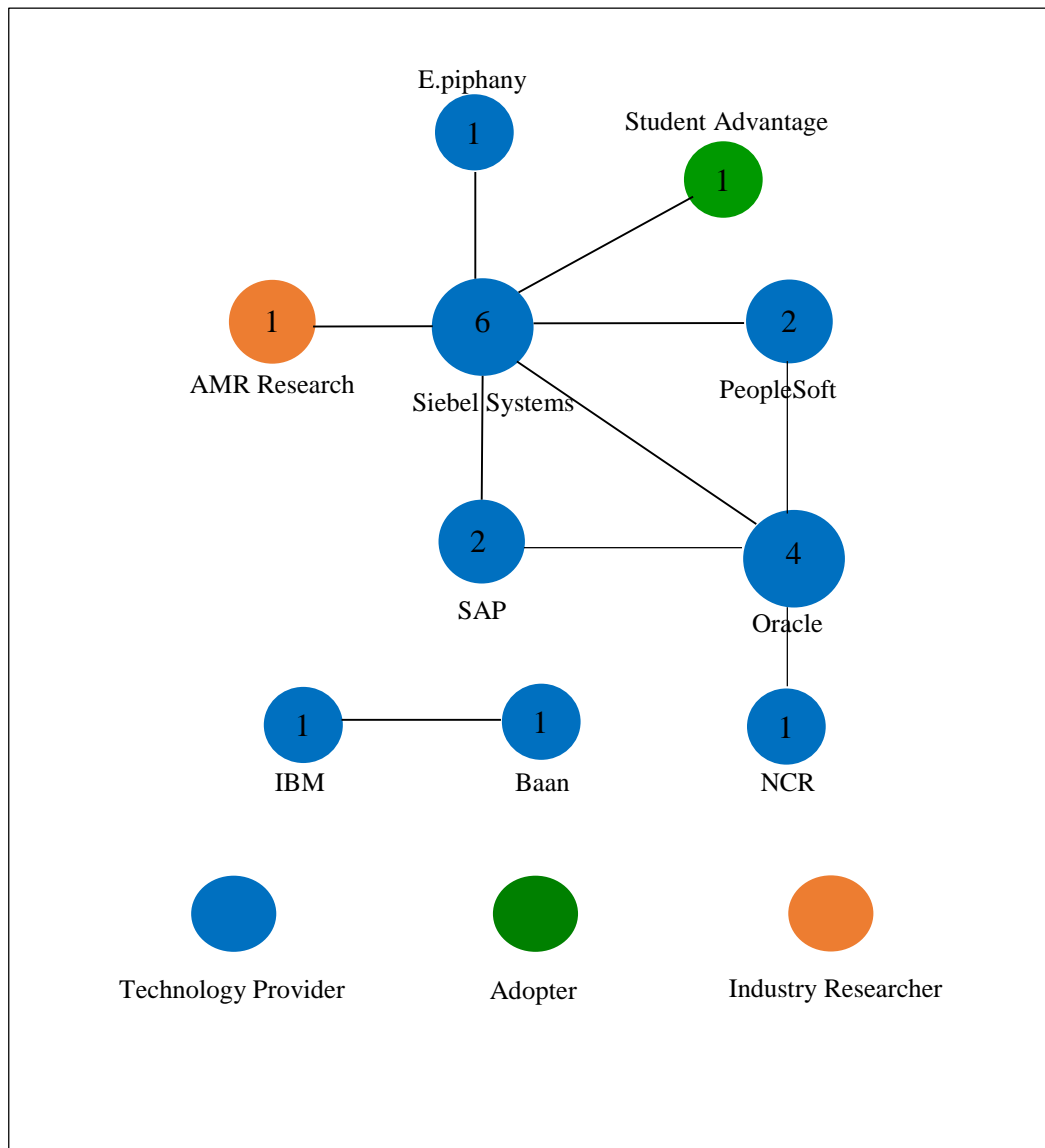
	Org Name	Degree	1	2	3	4	5	6	7	8	9	10
1	Siebel Systems	6		24	12	12	6	6	6			
2	Oracle	4								4	4	4
3	PeopleSoft	2				4						
4	SAP	2										
5	AMR Research	1										
6	E.piphany	1										
7	Student Advantage	1										
8	Baan	1										
9	NCR	1										
10	IBM	1										

In regard to S_{max} , let h be a graph with identical degree distribution to graph (g) and if all high-degree nodes are connected to other high-degree nodes, graph (h) reaches a maximum value named S_{max} . In order to construct a graph that has all highly-connected nodes connected to other highly-connected nodes, the first step is to break down the entire existing network (Figure 8.2) to identify nodes with high degrees in a descending order. For example, as summarized in Table 8.1, Siebel Systems has 6 degrees, Oracle has 4 degrees, PeopleSoft has 2 degrees, SAP has 2 degrees, AMR Research has 1 degree, E.piphany has 1 degree, Student Advantage has 1 degree, Baan has 1 degree, NCR has 1 degree, and IBM has 1 degree. Li et al. (2005) suggested that a new constructed network would have a unique S_{max} when: 1) all highly-connected nodes are connected to other highly-connected nodes in a descending order; and 2) nodes in the new network have identical degree distributions to the nodes in the existing network.

Beginning with the node which has the most edges (Siebel Systems, 6 edges) in Figure 8.1. Siebel Systems must be reconnected to other nodes that has high degrees in a descending order. For instance, since Siebel Systems has 6 edges in the existing network, Siebel Systems, therefore, has 6 “chance” to connect to other nodes with high degrees in the new network by following the rule “each node in the new network has an identical degree distribution to the nodes in the existing network” (Li et al., 2005). Accordingly, Siebel Systems is expected to connect with Oracle (4 edges), PeopleSoft (2 edges), SAP (2 edges), and any other three nodes that has only 1 edge in the new network. By following the same procedure, Oracle has 4 edges and is expected to connect with Siebel Systems (6 edges), PeopleSoft (2 edges), SAP (2

edges), and any one node that has only 1 edge in the new network. Similarly, PeopleSoft and SAP which have 2 edges are expected to connect with Siebel Systems (6 edges) and Oracle (4 edges). Last, there are 6 nodes that have only 1 degree and the rest two of them are expected to connect with each other, since any three of the 6 nodes have connected to Siebel Systems and any one of the 6 nodes has connected to Oracle. Figure 8.3 is a possible network illustration of S_{max} .

Figure 8.3 Possible Network Illustration of S_{max}



Based on the constructed network illustrated in Figure 8.3, in which all highly-connected nodes are connected to other highly-connected nodes, a unique S_{max} can be calculated. Table 8.2 summarizes a matrix table (top triangle) of nodes with new connections based on the rules described above, which results in S_{max} in the CRM technology provider network. By using the formula $s_{max} = \sum_{(i,j) \in \varepsilon} d_i d_j$, the maximized value of scale-freeness of CRM technology provider network in 2000 Q3 is 87. Therefore, the scale-freeness is calculated: $S(g) \frac{s(g)}{s_{max}} = 82/87 = 0.9425$.

Table 8.2 Matrix of Maximized Scale-freeness of CRM Technology Provider Network in 2000 Q3

Org Name		Degree	1	2	3	4	5	6	7	8	9	10
1	Siebel Systems	6		24	12	12	6	6	6			
2	Oracle	4			8	8					4	
3	PeopleSoft	2										
4	SAP	2										
5	AMR Research	1										
6	E.piphany	1										
7	Student Advantage	1										
8	Baan	1										1
9	NCR	1										
10	IBM	1										

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