

THREE ESSAYS ON NETWORKS AND KNOWLEDGE VALUE

by

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## Dedication

*To my inspiring parents*

*To my lovely wife, Rawan*

*To my beautiful children, Iyad and Taleen*

*To my supportive brothers and sisters*

*For their sincere prayers, unconditional love, and unlimited support that encouraged my pursuits*

## Acknowledgements

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Abstract

THREE ESSAYS ON NETWORKS AND KNOWLEDGE VALUE

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Knowledge creation is one of the factors that contributes the most to organizational performance and competitive advantage. Ample studies have employed network theory to examine the impact of various social capital and network-related features on the creation of new knowledge. However, some areas have been understudied or have not been explored yet. Thus, through three essays, this dissertation attempts to contribute to the literature by examining the relationships among networks, knowledge value, and firm performance. It advances our understanding of how the structure of networks changes, how some network characteristics affect the value of created knowledge, and how knowledge value contributes to firm performance. Using data from the National Basketball Association (NBA), the first study examines the impact of network resources and network's knowledge utilization on structural changes in networks. The second study investigates Saudi Arabian patents registered at the United States of Patents and Trademark Office (USPTO) to assess how network size and network diversity influence the value of created knowledge. The third study seeks to explore the relationships between the value of the knowledge created by firms and their

performance using data from the National Bureau of Economic Research (NBER) and USPTO on patents granted to biotechnological firms.



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## Chapter 1: Introduction

Knowledge creation is an important factor in economic development (Powell & Snellman, 2004). It is one of factors that contributes the most to organizational performance and competitive advantage (Eisenhardt & Martin, 2000; Grant, 1996; Kogut & Zander, 1996). Hence, scholars have studied knowledge creation for so long, focusing on factors and structures that influence knowledge creation amongst individuals, teams, and organizations (e.g. Grant, 1996; Kogut & Zander, 1992; McFadyen, Semadeni, & Cannella, 2009; Nahapiet & Ghoshal, 1998; Nonaka, 1994). A stream of research has particularly focused on the impact of relationships on knowledge creation. Specifically, scholars have employed network theory to examine the impact of various social capital and network-related features on the creation of new knowledge (e.g. McFadyen & Cannella, 2004; McFadyen et al., 2009; Perry-Smith, 2006; Schilling & Phelps, 2007). Throughout this dissertation, networks refer to sets of actors and the ties that connect them (McFadyen & Cannella, 2004; Nahapiet & Ghoshal, 1998).

The literature of networks and knowledge reflects one of the fastest growing streams of research (Phelps, Heidi, & Wadhwa, 2012). It spans multiple disciplines and unit of analyses. For example, at the individual level, sociologist, psychologist, and management scholars have studied the impact of several network characteristics on knowledge transfer and creativity (e.g. Bouty, 2000; Ibarra, 1993; McFadyen & Cannella, 2004; Perry-Smith, 2006). Research at the team (group) level, for instance, has examined the relationships among various network structures and knowledge transfer and knowledge creation (e.g. Reagans & McEvily, 2003; Tsai & Ghoshal, 1998; Tsai, 2001). Additionally, studies on network and knowledge at the

organizational level sought to investigate issues related to network structures and relations and how they influence knowledge transfer and knowledge creation (e.g. Ahuja, 2000; Funk, 2014; Smith, Collins, & Clark, 2005; Sytch & Tatarinowicz, 2014; Wang, Rodan, Fruin, & Xu, 2014).

Although previous studies have investigated ample areas related to network and knowledge creation, some areas have been understudied or have not been explored yet. For example, we know little about how networks evolve and how they come about. This is very important because our understanding of networks is not complete without knowing the genesis of network structures (Ahuja, Soda, & Zaheer, 2012). Also, previous studies on networks and knowledge creation focused mostly on how certain network structures and relations influence the amount of knowledge creation (e.g. McFadyen & Cannella, 2004), and very few have elected to examine their influence on the value of created knowledge. More importantly, an examination of knowledge creation in developing countries is rather scarce. Additionally, the findings on how knowledge creation impacts firm performance have been mixed, as positive, negative, and no relationships have been found in prior studies (e.g. Artz, Norman, Hatfield, & Cardinal, 2010; Ernst, 2001; Griliches, Hall, & Pakes, 1991). Importantly, the majority of such studies have focused more on the amount of knowledge creation, paying less attention to the value of created knowledge. While scholars have studied the impact of knowledge creation value on other economic indicators, such as stock market valuation (Hall, Jaffe, & Trajtenberg, 2005), there is no paper the author knows of that examined the direct impact of knowledge value on measures of firms' annual performance (i.e. return on assets or return on investment)

This dissertation seeks to contribute to the extant literature of networks and knowledge creation by addressing the gaps mentioned above. I pose three main questions that are addressed by each of the three studies that make up this dissertation. First, what network-related factors

could lead to changes in the structure of a network? Second, what network characteristics could increase a network of knowledge workers' opportunity to create valuable knowledge? Third, does the value of created knowledge influence the financial performance of firms?

The first study (chapter 2) is conducted at the network-level and uses data from the National Basketball Association (NBA) to examine factors that could change the structure of networks. Particularly, drawing from the resource-based theory (RBT), I argue that network resources in a season have a positive relationship with changes in network structure the following season. Additionally, I hypothesize that the average knowledge utilization of a network negatively impacts structural changes in networks. The findings show that when measured in terms of available cash (cap room), network resources have a positive impact on network change. However, the results were not significant when network resources were measured as the number of draft picks a team possesses. As for knowledge utilization, the findings of the study provide evidence that knowledge utilization in networks in season (p-1) negatively influences structural changes in networks in season (p).

The study offers three main contributions. First, unlike previous studies that examined how structure of past networks predicts the structure of future ones (e.g. Walker et al, 1997; Zaheer & Soda, 2009), or how previous ties affect the formation of future ones (e.g. Baum, Shipilov & Rowley, 2003; Gulati & Gargiulo, 1999); the study employs RBT to investigate the role of network resources in shaping the future structure of the network. Second, while others have found that knowledge creation of alters affects the addition and deletion of other alters in an ego's network (Cannella & McFadyen, forthcoming). For example, the first study in this dissertation contributes to the knowledge literature by studying how the level of knowledge utilization of an interpersonal whole network predicts changes in the network structure. Third, it



also responds to the call for employing network theory to study teams (Fewell et al, 2012; Katz, Lazer, Arrow, Contractor, 2004).

The second study (chapter 3) examines how some characteristics of networks of knowledge workers affect the value of their created knowledge. Using patents data from the United States Patent and Trademark Office (USPTO), it particularly aims to understand how network size and network diversity influence the value of knowledge created by knowledge workers from, or associated with, Saudi Arabia. The focus is on knowledge associated with a developing country because characteristics of knowledge and knowledge workers in such countries are likely to be different than those in developed countries, and because such examination should be helpful in addressing generalizability issues (Chua, forthcoming; Kotabe, Dunlap-Hinkler, Parente, & Mishra, 2007). Analyzing a sample of 228 patents, I find that both the size and diversity of a network of knowledge workers positively impact the value of created knowledge. However, contrary to what I predict, the interaction of network size and network diversity shows a negative relationship with knowledge value.

The findings of this study indicates that for knowledge workers in developing countries, having more members in the network could possibly increase the value of the knowledge they create. More importantly, having members from developed countries in the network makes creating valuable knowledge more likely. The study contributes to the extant literature on networks, knowledge creation, and international business by posing network characteristics by which knowledge workers in developing countries can create knowledge of high value.

The third study (chapter 4) moves beyond the network level of analysis and focuses on

firms. It examines the relationship between the value of knowledge created by biotechnological firms and their financial performance. It also assesses the moderating role of knowledge breadth on the aforementioned relationship, arguing that valuable and broad knowledge contributes to firm performance more than valuable, but less broad, knowledge. Matching patents data from the NBER and USPTO with firms' data from COMPUSTAT, the findings reveal that biotechnological firms that create knowledge of higher values are likely to have higher financial performance. Moreover, knowledge breadth is shown to positively moderate the relationship between knowledge value and firm performance.

The study contributes to the knowledge literature by examining the direct relationship between knowledge value and firm performance, unlike other studies that sought to estimate the market value of firms based on the value of the knowledge they create (e.g. Hall et al., 2005). Another contribution to the knowledge literature is that the study shows the importance of knowledge breadth and how it could positively increase the impact of knowledge value on firm performance, given the flexibility and opportunities that broad knowledge provides (Zhou & Li, 2012).

To summarize, the three essays collectively seek to shed some light on the relationships between networks, knowledge value, and financial performance. They advance our understanding of how the structure of networks change, how some network characteristics affect the value of created knowledge, and how knowledge value contributes to firms' financial success. In addition to advancing the extant literature on network theory, knowledge creation, and international business, the essays offer managerial insights on how to better build and manage networks of knowledge workers to create knowledge of high value. Figure (1-1) illustrates a summary of the relationships under consideration in this dissertation, and Table (1-1)

provides a summary of the three studies, including the variables and the research setting.

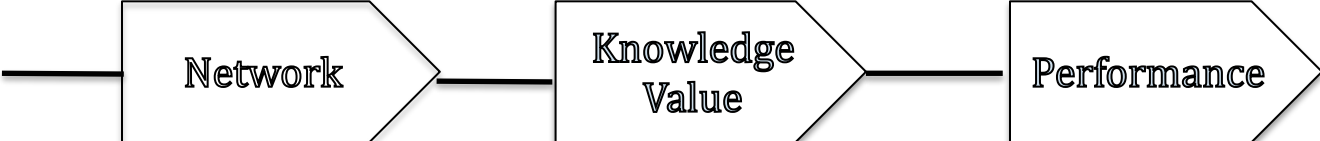


Figure 1-1: An overall framework of the relationships under consideration in this dissertation

Table 1-1: Summary of the three studies conducted in this dissertation

| Study                   | Main Research Question  | Dependent Variable | Independent variables  | Research setting  |
|-------------------------|---|--------------------|--|---|
| Study #1<br>(Chapter 2) | <i>How do network resources and knowledge utilization predict changes in network structure?</i>                             | Network Change     | <ul style="list-style-type: none"> <li>• Network Resources</li> <li>• Knowledge Utilization</li> </ul>   | National Basketball Association (NBA)                           |
| Study #2<br>(Chapter 3) | <i>How do network size and network diversity influence the value of knowledge created by networks of knowledge workers?</i> | Knowledge Value    | <ul style="list-style-type: none"> <li>• Network Size</li> <li>• Network Diversity</li> <li>• The interaction of network size and network diversity</li> </ul> | Patents granted by USPTO to Saudi Arabian assignees             |
| Study #3<br>(Chapter 4) | <i>Does the value of the knowledge created by firms impact their performance?</i>   | Firm Performance   | <ul style="list-style-type: none"> <li>• Knowledge Value</li> <li>• Knowledge Breadth (moderator)</li> </ul>   | Patents assigned by USPTO to biotechnological firms in the U.S. |

## Chapter 2:

### Network Resources, Knowledge Utilization, and The Dynamics of Networks: Evidence From The National Basketball Association

#### 2.1: Introduction

Network theory has been established as a major area of research in the literature of several disciplines (Borgatti & Halgin, 2011; Phelps et al., 2012). Research on interorganizational relationships (Galaskiewicz, 1985; Oliver, 1990) and network theory, in particular, has long informed us about the determinants and outcomes of such networks of relationships (e.g. Ahuja, 2000; Tsai, 2001). Actors form such relationships for various reasons, one of which is to acquire resources that tend to be beneficial to the focal actor (Galaskiewicz, 1985; Pfeffer & Salancik, 1978; Oliver, 1990). Scholars interested in network theory have examined theories of closure (Coleman, 1988) and structural holes (Burt, 1992), emphasizing the advantages and disadvantages of being in close and sparse relationships. They have also focused on features such as network density (e.g. McFadyen et al., 2009) and positions of actors within networks (e.g. Powell, Koput, & Smith-Doerr, 1996; Tsai & Ghoshal, 1998). Moreover, some researchers have studied the impact of tie strength on individual, group, and organizational outcomes (e.g. Granovetter, 1973; McFadyen & Cannella, 2004).

Despite the explosion of research on network theory (Borgatti & Halgin, 2011;

Phelps et al, 2012), there are still some gaps that need to be addressed. The majority of network research is built on the assumption that networks are static, despite findings asserting that networks evolve and change over time (e.g. Gulati & Gargiulo, 1999; Madhavan, Koka, Prescott, 1998; Nohria, 1992). Few studies have acknowledged networks as a dynamic phenomenon (Powell, White, Koput, & Owen-Smith, 2005). For example, some studies have found that bridging ties decay over time (Burt, 2002). Others have demonstrated how past structures of a network and performances of actors affect the formation of future networks (e.g. Gulati, 1995; Walker, Kogut & Shan, 1997; Zaheer & Soda, 2009). In a more recent study of knowledge workers (i.e. researchers), Cannella and McFadyen (forthcoming) found that network density among researchers' direct exchange partners predict the addition of new members; and that tie strength between ego and alters predict the drop of existing members. They also found evidence that several components of knowledge creation of alters influence the addition to, or the deletion of, alters from an ego's network. Additionally, Sytch and Tatarynowicz (2014) studied network communities and found that firms are more likely to invent when their rate of movement across communities is moderate. Their findings also indicate that firms in central positions benefit more from membership dynamics than those in peripheral positions.

It is essential for scholars of network theory to progress in researching dynamic networks, because, as put by Ahuja, Soda, and Zaheer (2012:434), “ an understanding of network outcomes is incomplete and potentially flawed without an appreciation of the genesis and evolution of the underlying network structures.” In an attempt to contribute

to this line of research, the current study examines factors that predict change in interpersonal whole networks (Provan, Fish, & Sydow, 2007). An interpersonal whole network reflects relationships among individuals in a bounded population (Phelps et al, 2012). Thus, changes to an interpersonal whole network, for example, can come about in the form of addition or deletion of actors, or rather by forming new relationships or dissolving existing ones (Ahuja et al, 2012). For the purpose of this paper, nodal structural change is examined. That is, I study the deletion of an actor and the addition of another one as a replacement, which leads to new ties among network members.

Research posits that studying network change in terms of tie creation (addition) and dissolution (deletion) provides more clarity and tractability to theory and methods (Koka, Madhavan & Prescott, 2006). Network change can be attributed to actor-related factors, such as actors' tendency to establish ties with beneficial partners at the expense of less beneficial ones (Ahuja et al, 2012), or environmental factors such as technological shocks or environmental uncertainty (Koka et al, 2006). Alternatively, network change can occur as a result of network-related attributes, such as past and current network structures (Gulati, 1995; Nohria, 1992) or the opportunities available for the network (Koka et al, 2006).

In the current study, I examine the impact of two network-related factors that could influence network change. Specifically, drawing from the Resource-Based Theory (RBT) (Barney, 1991), I predict that a network's internal resources have a positive impact on network change. Also, building upon the "agency-driven" micro-foundation of network dynamics (Ahuja et al, 2012), I suggest that the average level of knowledge

utilization among network members is negatively associated with network change.

Knowledge utilization is defined as the overall ability of networks to process and apply their knowledge (Duncan, 1972; Inkpen, 2000; Rich, 1979). Thus, I predict that members with lower levels of knowledge utilization are deemed unbeneficial for the network and are more likely to be replaced by new members. Figure (2-1) depicts the conceptual model of the current study.

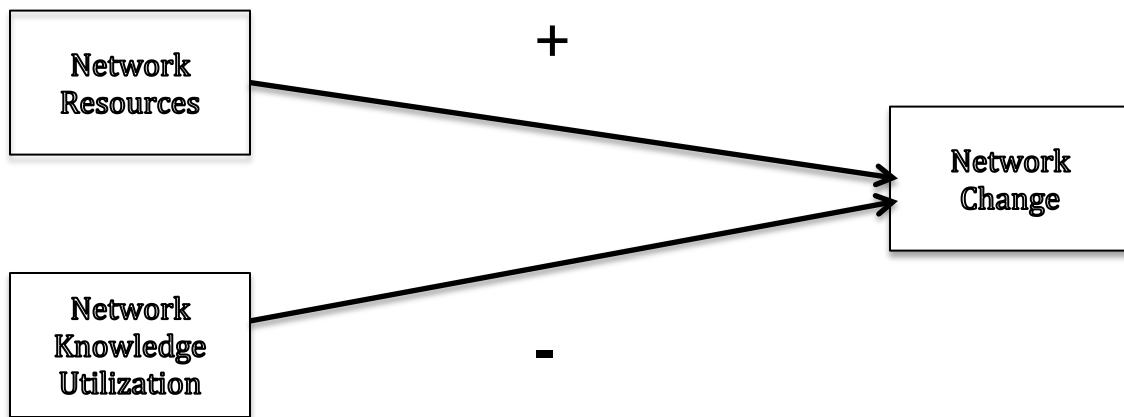


Figure 2-1: The impact of network resources and knowledge utilization on network change

In order to test the hypotheses of this study, the context has to meet certain criteria. First, it has to be one in which the network elements are available and changeable. That is, there have to be actors collaborating and interacting with each other and some sort of network change must be viable. Second, the actors have to possess utilizable knowledge to eventually influence their performance. For the aforementioned reasons, the current study is conducted within the NBA context. Sports provide an



appropriate context in which to study organizational phenomena due to the similarities between sports and other industries (Day, Gordon, and Fink, 2012; Fonti & Maoret, forthcoming; Rowe, Cannella Jr, Rankin, & Gorman, 2005). For instance, teams in organizations and sports are goal-oriented and collaborate to achieve high performances (Katz, 2001). Sports settings also provide accurate and transparent data that allow for objective analysis for teams competing in a relatively controlled environment (Day et al., 2012; Fonti & Maoret; forthcoming).

In using basketball data, I follow the lead of established scholars who have incorporated data from the NBA in their organizational research. For example, Pfeffer and Davis-Blake (1986) investigated the impact of managerial succession on the performance of NBA teams. More recent studies relied on basketball data and employed network theory to study the effectiveness of offensive strategies among basketball teams (Fewell et al., 2012), and to predict team performance (Fonti & Maoret, forthcoming). Also, Staw and Hong (1995) examined the relationship between sunk cost and decision-making about players' playing time, whereas Berman, Down, and Hill (2002) explored how tacit knowledge in NBA teams is related to competitive advantage. In the following section, I will discuss how the NBA is an appropriate context for the current study.

Overall, the present study aims to achieve several contributions. First, it contributes to the emerging literature of network dynamics by studying factors that affect network changes. Previous studies have examined how structure of past networks predict the structure of future ones (e.g. Walker et al, 1997; Zaheer & Soda, 2009). Others posited that previous ties affect the formation of future ties (e.g. Baum et al., 2003; Gulati

& Gargiulo, 1999). Koka et al (2006) theoretically proposed that changes in the environment lead to four types of network changes-- network expansion, network churning, network strengthening, and network shrinking. In this study, I employ RBT to investigate the role of network resources in a period in shaping the network structure in the following period (season).

Second, the study contributes to the knowledge literature by studying how the level of knowledge utilization of an interpersonal whole network predicts changes in network structure. Others have concluded that knowledge creation of alters affects the addition and deletion of other alters in an ego's network (Cannella & McFadyen, forthcoming). Instead, I examine how the average level of knowledge utilization of an interpersonal whole network (team) in a period leads to changes in the network the following period. Third, the study contributes to the literature that studied organization using sports data. Despite evidence of similarities between organizations and sports, organizational scholars are slow to adopt sports data in their research (Day et al, 2012). Sports provide an excellent opportunity to study organizational phenomena objectively. Additionally, the study responds to the call for using network theory to study teams (Fewell et al, 2012; Katz et al., 2004).

The rest of the paper is structured as follows. In the next section, I discuss theory and provide arguments on network change, network resources, and knowledge utilization in the NBA. I follow that with the methodology section, where I discuss the sample, measures of variables, and the analytical technique used to test the hypotheses. The paper closes with the results and discussion sections, providing some managerial implications

and areas for future research.

## 2.2: Theoretical Background and Hypotheses Development

### 2.2.1: Network Change

The architecture of networks generally consists of three parts—the nodes that comprise the network, the ties that connect them, and the patterns of these connections (Ahuja et al, 2012). Thus, network change generally refers to changes in any of these parts. For example, a change in the nodes of a network might be made by adding, dropping, or substituting a partner with another one that has different characteristics (Borgatti & Halgin, 2011; Bouty, 2000). Likewise, a change in the ties that connect nodes could take place by strengthening or weakening an existent tie. Both strong ties and weak ties are beneficial. Strong ties indicate increased interaction and result in trust between partners if the ties are mutually beneficial, which researchers have found to be the only way to transfer tacit knowledge (e.g. Hansen, 2002; Reagans & McEvily 2003). On the other hand, weak ties may expose actors to diverse knowledge and provide more opportunities for creativity (Granovetter, 1973) and transfer of explicit knowledge (Hansen, 1999). Thus, it is concluded that actors could indulge in different types of ties that match their strategies. The third form of network change could be a change of the pattern of connections among actors. That is, a network can change from dense to sparse or vice versa, as each provides different environments and facilitate different outcomes (Ahuja, 2000; Burt, 1992; Coleman, 1988).

The current study examines changes of actors in an interpersonal whole network. Specifically, I examine factors that lead to the deletion of an actor and the ties associated

with him, and the addition of a replacing one in networks of knowledge workers. Such modification could be initiated by the actors themselves or by external factors that affect the network. For example, an actor can make a decision to cut ties with one of his/her partners if he/she feels that partner is no longer beneficial. This is an agency-driven behavior that supports the notion that actors tend to establish favorable connections and dissolve unfavorable ones (Ahuja et al, 2012). In this paper, for example, I test how actors might experience changes in their networks based on the favorability of knowledge utilization of their partners.

On the other hand, other network-related factors that are out of the actors' control can force them out of their current network. Such factors that contribute to network change can be driven, for example, by an opportunity that presented itself (Ahuja et al, 2012). In such situations, substitutions of partners can be established based on the availability of resources within the network boundaries or on the proximity of other options (Rivera, Soderstrom, & Uzzi, 2010). The current paper employs RBT (Barney, 1991; ) to investigate the impact of network resources on changes in network structure.

### 2.2.2: Networks and NBA Teams

As mentioned earlier, sports represent an appropriate context in which to study organizational phenomena. Basketball teams have been used commonly as a focus of network analysis in the literature (e.g. Fewell et al, 2012; Fonti & Maoret, forthcoming). Basketball is an ideal sport to study network-related issues because it has high levels of interdependence among players (Berman et al., 2002). For example, players rely on other players to assist or set a screen for them on offense, while they can collaborate to double-

team players from the opposing team on the defensive end. Basketball players are also ideal for knowledge-related studies as the skills they possess are representative of tacit knowledge (Berman et al, 2002, Polanyi, 1969). In fact, the collective skills of basketball players is a form of “group tacit knowledge,” in which the knowledge shared among actors is tacit, embedded in actions, and includes collective practical skills, expertise, and cognitions (Erden, von Krogh, & Nonaka, 2008; Wegner, Giuliano, & Hertel, 1985). Such knowledge is usually tied to the movement skills and physical experiences of the players (Erden et al., 2008; Polanyi, 1966). Unlike explicit knowledge, tacit knowledge cannot be codified or articulated, and thus are harder to transfer (Nonaka, 1994; Zander & Kogut, 1995). For basketball players, the ability to shoot from a distance or the ability to play hard defense are skills that players possess, but cannot document or codify in order to transfer it to other players.

In addition, recent research advocates the application of network theory to study teams or small groups (Katz et al, 2004). Katz and her colleagues argue that network analysis offers a great tool to examine team-level phenomena, especially those that span different levels of analysis. Network theory provides the opportunity to study important team features, such as the relationships between nodal capability and team performance, how nodal change affects the dynamic functions of the team, and how the pattern of relationships among team members affects team performance (Borgatti, Mehra, Brass, & Liobanca, 2009; Cummings & Cross, 2003). Thus, basketball teams represent a suitable context that network theory could be applied to study (Fewell et al., 2012; Fonti & Maoret, forthcoming), given the group tacit knowledge that players share on the court

(Erden et al., 2008). For instance, network theory can help predict how the capability of one node (i.e. player) affects the team's overall performance. Also, network analysis can help explain how the pattern of interactions among players affects team performance, and how the change of players over time influences team performance. An example of studying basketball teams using network analysis is a study that explored the dynamics of players' interactions to assess the differences between offensive strategies among NBA teams (Fewell et al, 2012). A more recent study by Fonti and Maoret (forthcoming) adopted a more dynamic approach to network theory in order to measure the impact of relational stability between core and peripheral players on team performance.

Like other sports, players change their teams frequently in the NBA, which allows for the test of network change. Changes in an NBA team come about via multiple options. A main option is via free agency, a situation in which players with expired contracts can sign with any team. There is also the NBA draft, an annual event in which teams acquire new basketball players from colleges and international leagues. Finally, players can also be moved by being traded to other teams. A trade is a situation where two teams or more reach an agreement to exchange players, considering the teams' respective cap room.

### 2.2.3: Network Resources

Like organizations, the goal of network formations is to achieve certain goals, such as acquiring resources (Eisenhardt & Martin, 2000; Pfeffer & Salancik, 1978), or creating value that gives networks a sustainable competitive advantage (Barney, 1991; Porter, 1985). Thus, for networks to be effective, it is essential to have members with

valuable resources (Gulati, 2007; Lavie & Miller, 2008). Indeed, it is vital when building networks to pay attention to actors and the structure of their relationships (Nohria, 1992; Koka et al, 2006). However, while collaborating with others and having access to resources sounds beneficial, the cost of coordination and maintenance underlying such relationships should be considered (Burt, 1992; Gulati & Singh, 1998). In other words, when building a network of relationships, actors are constrained by the resources and opportunities available to them.

RBT has been powerful in describing, explaining, and predicting organizational outcomes and relationships (Barney, 1991; Barney, Ketchen, & Wright, 2011; Wernerfelt, 1984). Although RBT is traditionally conceptualized at the organizational-level, research has extended the theory to team-levels (e.g. Gardner, Gino, & Staats, 2011), as teams are usually responsible to perform organizational activities. The main premise of RBT is that internal resources of organizations contribute to their sustainable competitive advantage (Barney, 1991; Conner, 1991). In addition to explaining sustainable competitive advantages of organizations, the theory has been employed to predict other favorable organizational outcomes, such as profits (e.g. Peteraf, 1993), diversification strategies (e.g. Chatterjee & Wernerfel, 1991), and strategic alliances (e.g. Das & Teng, 2000). Building upon research on RBT and strategic alliances, I argue that the internal resources of networks influence their evolution. Specifically, I suggest that the more resources a network has, the more likely it is to experience structural change. It should be noted that network internal resources are different than the concept of munificence in the environment literature (Dess & Beard, 1984) in that the latter is an

environmental concept that refers to the extent of resources available in the environment (Castrogiovanni, 1991), while the former are strictly internal resources that no other network is competing for.

For NBA teams (networks), there are two types of resources that they can utilize to acquire new players (actors). First, teams have cash that they can spend to acquire free agents in the off-season. However, teams are limited on the cash they can spend. The NBA has a salary cap of total salaries allocated to players of each team every season. The cap exists as a mean to enhance parity among teams, preventing rich teams from signing all the talented players. Cap room is the amount of cash available for teams to sign new players in free agency (i.e. salary cap minus total salaries of current players). However, because the salary cap in the NBA is soft, allowing teams exceptionally to go above the cap, I focus on the luxury tax threshold as a base to calculate the cap room of each team. The luxury tax threshold is a maximum total salary for a team, beyond which the team has to pay a luxury tax. In this perspective, I argue that teams below the luxury tax threshold have more resources to acquire new players and thus, changing the structure of their network. Likewise, teams at or above the luxury tax threshold are less likely to acquire additional players due to the tax penalties they would incur.

Second, the NBA has a draft system that allows each team to select college or international players before each season. Regularly, each team has two draft picks each season. However, since draft picks are used frequently in trades, teams can have more or less than the two original draft picks they are awarded from the NBA. Drawing from the arguments developed above, I argue that teams with more draft picks are more likely to



have changes in their lineups the following season than teams with fewer draft picks.

Therefore:

*Hypothesis 1: There is a positive relationship between network resources in period (p-1) and network change in period (p).*

#### 2.2.4: Knowledge Utilization

The literature of knowledge utilization is old and encompasses multiple disciplines, including public policy, medicine, communication, marketing, and sociology, among others (Rich, 1979). Knowledge utilization has been conceptualized somewhat differently among disciplines, but all of them emphasize the point that knowledge utilization represents an extent to which one can process and convert knowledge into tangible outcomes. Thus, researchers of knowledge and innovation often relate knowledge utilization to processes, such as knowledge integration (Eisenhardt & Schoonhoven, 1996; Inkpen, 2000), knowledge application (Grant, 1996, Inkpen, 2000), knowledge commercialization (Kogut & Zander, 1996; Cohen & Levinthal, 1990), and innovation (Miller, Fern, & Cardinal, 2007; Vasudeva & Anand, 2011). In this paper, I define knowledge utilization as the network's overall ability to leverage the knowledge of its actors to influence a network-level outcome.

In the network context, actors generally form alliances to achieve a desired outcome such as acquiring resources, complying with new regulations, or to gain control over partners (Oliver, 1990). Resource-dependence theory also asserts that acquiring resources is a strategic rationale for network formation (Pfeffer & Salancik, 1978). One of the highly sought-after resources is knowledge (Bouty, 2000; Kogut & Zander, 1992;

Reagans & McEvily, 2003). Actors tend to acquire knowledge as a mean to facilitate others goals, such as high performance (Oliver, 1990; Stuart, 2000) or innovation (Ahuja, 2000; Mihalache et al, 2012; Powell et al., 1996). However, when actors realize that the current structure of their network with its existing members, does not enable them to achieve their goals, a form of change is likely expected.

Thus, if actors are not capable of utilizing their knowledge in their existing networks, they might decide to re-structure their network of partners as a way to improve their knowledge utilization capability. In fact, as Kogut and Zander (1992) assert, the knowledge of individuals is not valuable in itself; rather, it gains value when combined with other capabilities that provide them with ideal environments to be beneficial. The agency-driven behavior, as one of the rationales for network formation, also suggests that actors deliberately seek collaborations that give them more chances to succeed (Ahuja et al, 2012, Burt, 2005; White, 1992). As noted by Ahuja et al (2012), the result of such connections is a network structure initiated by self-seeking actors. Thus, I submit that the structure of networks is partially influenced by the ability of network members to effectively interact with each other.

Another theory that has been used in the literature to explain the interdependency among members of teams and networks is the theory of transactive memory systems (Hollingshead, 1998; Wegner et al., 1985; Wegner, 1987). The theory has been specifically important in explaining interdependency among individuals in knowledge-based environments (e.g. Gardner et al, 2011; Lewis, 2004), as in the case of players in a basketball team. The theory explains how each network member, with his own repertoire

of skills, influences and leverages the skills of other network members through a network of communication links. According to the theory, those communication links allow team members to know where each skill is located within the team, which reduces the time required to accomplish goals and eventually improves performance (Katz et al, 2004). Therefore, it is safe to conclude that network members, the structure of their relationships, and the pattern of their interactions, have an impact on each member's ability to utilize his skills. Consequently, with high levels of effective interactions, network members are expected to achieve higher outcomes. On the other hand, whenever actors are not able to effectively utilize their knowledge while members of their current networks, they are expected to move to other networks. Such a move can introduce them to better opportunities to utilize their knowledge.

In the NBA, teams strive to construct a network of five players on the court in a way that maximizes the network overall performance (figure 2-2). As tacit knowledge, the skills of each player are the main target of player acquisitions. It is of significant importance to have players with a set of skills that could be combined for the benefit of the team. Skills of basketball players include those that players need in the offensive side of the basketball such as shooting and passing, and the defensive ones such as shot-blocking and stealing. Drawing from the agency-driven behaviors of network members and the theory of transactive memory described above, I posit that the ability of players to utilize their skills depends partially on the skills of their teammates and their ability to interact with each other.

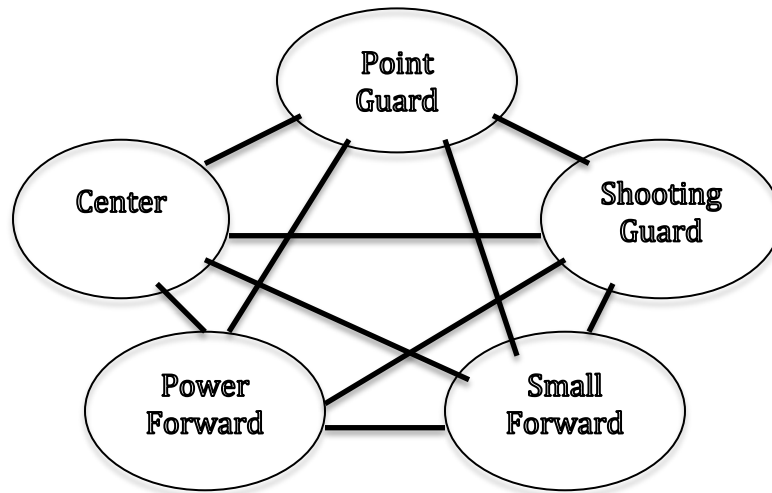


Figure 2-2: A network of five basketball players

It should be noted that change among NBA players could be the result of a decision by network builders (i.e. team officials), if they deem the focal player less beneficial for the network's overall ability to utilize its knowledge. Alternatively, a player could decide to leave the team via free agency or by requesting a trade when he feels the current structure of his team does not allow him to better utilize his skills. Either way, when a team decides to move a player or when a player makes a decision to leave the team, the result is that there is a change in the team's structure. As a result, from a network perspective, there is a nodal change in the network. Thus:

*Hypothesis 2: There is a negative relationship between networks' level of knowledge utilization in period (p-1) and network change in period (p).*

## 2.3: Methods

### 2.3.1: Sample

To resemble networks, professional basketball teams from the National Basketball Association were used in the current study. Data were collected on the five players that played together the most for each team in nine consecutive seasons-- from the 2005-2006 till 2013-2014, inclusive. The decision to collect data starting from the 2005-2006 is due to the establishment of the Charlotte Bobcats (now the Hornets) in 2004 as the last franchise to join the NBA. As a first-year team, there was no data on the Charlotte Bobcats' previous season. Therefore, I collected data on all teams from the following season (i.e. 2005-2006). It should be noted that when teams changed cities, names, or both, I considered them the same team. The final sample consisted of 30 teams over nine seasons, resulting in 270 team-season observations.

The decision to examine the players that played the most for each team in each season, instead of just choosing the regular starters of each team was made because some starters play for a very short time of the game. Hence, they are not considered "core" players of the team (Fonti & Maoret, forthcoming). For example, in the 2013-2014 season, Jamal Crawford of the Los Angeles Clippers was a bench player most of the time. However, while he did not start a lot of games, he was third among his teammates in minutes played and was available on the court most of the time to play with the starters and the core players in the team.

Data on the five players that played together the most were obtained from

82games.com, a website that provides advanced data and statistics about NBA teams and players. It provides all the combinations of players that played for a team in each season with the total minutes they have been on the court together. I chose the combination that was ranked first for each team to conduct my analysis.

### 2.3.2: Dependent Variable

2.3.2.1: *Network change*. To measure network change, I compared the list of five players that played together the most in a team from a period ( $p-1$ ) with the list from the following period ( $p$ ). Then, I counted the number of players who were listed in ( $p-1$ ) and replaced in ( $p$ ).

### 2.3.3: Independent Variables.

2.3.3.1: *Network resources*. As explained earlier, two resources are available for NBA teams to acquire players—cap room and draft picks. First, because the salary cap in the NBA is soft, allowing teams exceptionally to go above the cap, I elected to use the luxury tax threshold as a base to calculate the cap room of each team. Thus, using data from *Spotrac.com*, each team's cap room was calculated by subtracting its total salaries from the luxury threshold before the beginning of each season.

Second, I counted each team's final number of draft picks after all trades are accounted for. For more accuracy, I used a weighting scheme to assign higher weights to higher draft picks to account for the quality of drafted players and the probability of them playing significant parts in their teams the following season. For example, a player selected early in the draft (e.g. top five) is more likely to play more minutes and be

amongst the five players that represent a team regularly than a player drafted in the second round. Therefore, I classified the 60 draft picks available each season into five categories. The first category includes the top five draft picks, while the second, third, and fourth categories include the draft picks from 6-10, 11-20 and 21-30, respectively. All picks of the second round (i.e. from 31-60) are grouped into the fifth category. The weighing system multiplies the total number of teams' draft picks in the first category by five, while total number of draft picks in the second, third, and fourth categories are multiplied by four, three, two, respectively. On the other hand, draft picks of the fifth category are all multiplied by one. For example, if a team has two draft picks, one in the top five and one in the second round, its draft weighted-measure equals  $[(1*5) + (1* 1)]= 6$ . I used both cap room and draft picks as two measures of network resources in the analysis.

*2.3.3.2: Knowledge utilization.* Previous research has measured knowledge utilization in terms of an actor's ability to process knowledge and apply it to produce an output. For example, Vasudeva and Anand (2011) used patents to measure how alliances influence knowledge utilization. In the basketball context, a measure is needed to represent each team's ability to utilize the knowledge of its players. I used Player Efficiency Rating (PER) to measure knowledge utilization of NBA players. A common measure in organizational literature that used basketball data (e.g. Fonti & Maoret, forthcoming), PER captures the overall contribution per-minute of a player. The measure was developed by John Hollinger's, formerly of ESPN, to account for the positive as well as negative impacts of a player. Rather than focusing on one skill such as scoring ability, for

example, PER takes into account other skills such as ability to assist, block, as well as other individual skills. Importantly, it standardizes the statistic for by each player for minutes played and also factors in the pace of the offensive and defensive strategies of the player's team. Thus, PER is appropriate to measure both offensive and defensive skills utilization of a player. As developed by Hollinger, the average PER is set to 15.0, which allows for comparison among players. Knowledge utilization of each team was measured as the average PER of the five players that played together to represent each team in (p-1). PER data were collected from *Basketball-reference.com*, a reliable website for basketball statistics.

#### 2.3.4: Control Variables

I included several control variables that might influence network change in the NBA. First, because teams with low performances are more likely to experience changes in their structure, I included teams' performance from the previous season (i.e. *lagged performance*) as a control variable. Lagged performance was measured as the percentage of wins of each team in the previous regular season (p-1). I considered the regular season only to maintain consistency among teams that made and did not make the playoffs.

Second, because past network structure might affect future structure (Gulati & Gargiulo, 1999), I included *lagged change* to control for network changes in the previous season.

That is, I expect teams that changed their five main players in a season are less likely to undergo other changes in the following season.

Additionally, to account for other factors that might influence personnel changes in each team, I controlled for changes in *coaches*, *general managers*, and *owners*. Those



individuals make decisions that affect players' movement among teams. They make decisions on signing, drafting, and trading for players who match their organizations' culture. The coach, specifically, makes decisions about whom to play on the court and for how long, depending on the coach's strategy (Wright, Smart, & McMahan, 1995).

### 2.3.5: Analysis

The dependent variable in this study, network change, is a nonnegative count measure that takes on only nonnegative integer values. I follow recent research (e.g. Funk, 2014) that employed a conditional fixed-effects quasi-maximum-likelihood Poisson regression as an analytical methodology. I use fixed-effects models to control for any time-invariant unobserved heterogeneity in changes among teams' lineups. While the negative binomial models are very common when dealing with count measures, the Poisson models have some advantages that make it appropriate for this study. First, the Poisson approach is less strict than the negative binomial in terms of distributional assumptions, and it provides consistent estimates if the conditional mean is correctly specified (Gouriéroux, Monfort, & Trognon, 1984). Additionally, I use the *vce (robust)* command in the STATA statistical package to control for any violations in the underlying assumptions (Cameron & Trivedi, 2009; Huber, 1967).

Second, there was no major issue with over-dispersion in this study, which is a case in which negative binomial models are more appropriate (Hausman, Hall, & Griliches, 1984). Nonetheless, using the quasi-maximum-likelihood Poisson standard errors is a robust check that deals with over-dispersion (Funk, 2014).

## 2.4: Results

Table (1-1) presents the mean, standard deviations, and correlations for the variables included in the models. The data were examined for assumptions of normality and multicollinearity. The dependent variable followed a negative binomial distribution, and all other variables approximated normal distributions. Because the methodology used in the analysis was a maximum likelihood one, no statistics such as variance inflation factors (VIFs) were available. However, I ran some procedures to check for any multicollinearity issues. First, I examined the correlation metrics to check if any variables are highly correlated. The matrix didn't show a significant problem that would affect the results, even when omitting some variables from the analysis. Second, I ran the analysis with one independent variable at a time and the results did not show changes in signs or significance level. These analyses suggest that multicollinearity was not an issue that affected the results of this study.

Table 2-1: Descriptive Statistics

| Variable             | Mean  | SD   | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     |      |
|----------------------|-------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|------|
| Network Change       | 2.25  | 1.20 | 1.00  |       |       |       |       |       |       |       |       |      |
| Age                  | 26.7  | 2.40 | 0.04  | 1.00  |       |       |       |       |       |       |       |      |
| Salary               | 6.95  | 2.42 | -0.10 | 0.59  | 1.00  |       |       |       |       |       |       |      |
| Network Change (p-1) | 2.24  | 1.18 | 0.26  | -0.23 | -0.30 | 1.00  |       |       |       |       |       |      |
| Performance (p-1)    | 0.50  | 0.15 | -0.22 | 0.52  | 0.48  | -0.43 | 1.00  |       |       |       |       |      |
| New Coach (p-1)      | 0.40  | 0.60 | 0.17  | -0.13 | -0.08 | 0.09  | -0.30 | 1.00  |       |       |       |      |
| New Coach (p)        | 0.09  | 0.29 | 0.11  | -0.15 | -0.12 | 0.12  | -0.23 | -0.02 | 1.00  |       |       |      |
| Cap Room             | 0.98  | 12.5 | -0.07 | -0.45 | -0.50 | 0.20  | -0.40 | 0.02  | -0.03 | 1.00  |       |      |
| Weighted_Draft       | 4.13  | 2.49 | 0.09  | -0.37 | -0.35 | 0.27  | -0.60 | 0.23  | 0.14  | 0.33  | 1.00  |      |
| Knowledge            | 16.15 | 1.44 | -0.34 | 0.31  | 0.46  | -0.29 | -0.42 | -0.15 | -0.18 | -0.15 | -0.26 | 1.00 |
| Utilization          |       |      |       |       |       |       |       |       |       |       |       |      |

Table 2-2: The Poisson Regression Models Predicting Network Change

| Variable                    | Model 1            | Model 2            |
|-----------------------------|--------------------|--------------------|
| Age (p)                     | 0.07**<br>(0.02)   | 0.05*<br>(0.02)    |
| Salary (p)                  | - 0.03<br>(0.28)   | - 0.01<br>(0.02)   |
| Network Change (p-1)        | 0.04<br>(0.02)     | 0.02<br>(0.02)     |
| Performance (p-1)           | - 0.60**<br>(0.32) | - 0.07**<br>(0.28) |
| New Coach (p-1)             | 0.09<br>(0.05)     | 0.07<br>(0.05)     |
| New Coach (p)               | 0.06<br>(0.06)     | 0.01<br>(0.02)     |
| Cap Room (p-1)              |                    | 0.01*<br>(0.00)    |
| Weighted_Draft              |                    | - 0.1<br>(0.01)    |
| Knowledge Utilization (p-1) |                    | - 0.12**<br>(0.02) |
| Wald $\chi^2$               | 37.09              | 110.06             |
| Log-likelihood              | -350.25            | -343.86            |

All models are derived from maximum-likelihood Poisson specification with robust standard errors (reported in parentheses). \* p <.05 , \*\* p < .01

In the Poisson regression, I entered the variables as blocks to assess the incremental explanatory power of each block. Table (2-2) shows the results of the Poisson regression. Model 1 represents the base model, in which only the control variables and the dependent variable are included.

In model 2, the independent variables were included to test the hypotheses of interest in this study. Hypothesis 1 suggested a positive relationship between network resources in ( $t-1$ ) and network change in ( $t$ ). Two measures of network resources were used in the analysis. First, when cap room was used, a positive and significant relationship existed between network change and network resources ( $\beta = 0.01, p < 0.01$ ). The results indicate that teams with more cap room are more likely to replace a core player, thus, support hypothesis 1. However, the hypothesis was not supported when draft picks were used as a measure of network resources ( $\beta = -0.01, p > 0.05$ ).

In hypothesis 2, I predicted that knowledge utilization in period ( $t-1$ ) is negatively associated with network change in period ( $t$ ). As shown in model 2, the analysis provides support for the hypothesized relationship, with a negative and significant coefficient ( $\beta = -0.12, p < 0.01$ ). The results provide evidence that when teams are more able to utilize the skills of their players, it is less likely that they undergo major changes in their core players.

## 2.5: Discussion

Network theory has been employed frequently to study various organizational phenomena. However, most of the research has dealt with networks as static and rarely has examined their dynamics (e.g. Gulati & Gragiulo, 1999; Cannella & McFadyen,

2009). To fully understand networks and this related phenomena, scholars must study antecedents of network structures, as well as their outcomes. In this study, I focus on network dynamics and examine factors that predict network change. Specifically, I examine how network resources and network knowledge utilization influence nodal changes in networks of knowledge workers.

Studying basketball teams as networks of knowledge workers, the current paper provides evidence that teams with more resources are more likely to experience changes in their core players. RBT suggests that valuable resources of a network are significant predictors of network outcomes, including those related to the formation of relationships (Das & Teng, 2000). The availability of resources provide network with opportunities to, for instance, explore different alternatives, to indulge into various strategies, and to attract key and powerful actors. In the NBA, the findings assert that teams with more cash; as one form of network resources, are more likely to sign new players to their squad. However, when network resources were measured as the availability of draft picks, the findings were not as predicted. An explanation could be that unlike free agents acquired using available cash; draftees are young or new players who lack the experience that enables them to play major roles in their teams. Thus, most draftees tend to be secondary players on their teams, especially those selected later in the draft. Overall, with the belief that financial resources are more common of a resource that applies to all industries, the findings show that network resources, indeed, contribute to changes in network structure. This supports recent evidence that associate increases in public capital market with the formation of new partnerships (Hoehn-Weiss & Barden, 2014).

The findings on the impact of knowledge utilization on nodal changes in networks were as predicted. When network members benefit from their existing relationships, they are less likely to replace their partners. As informed by the resource-dependence theory (Pfeffer & Salancik, 1978), actors indulge in relationships to have access to resources they do not possess. As an important resource, knowledge is one of the most coveted resources that actors seek to acquire (Grant, 1996; Grant & Baden-Fuller, 2004). The ability to exploit and utilize acquired knowledge become crucial for actors in order to achieve desired outcomes. Thus, when the current structure of their network does not allow them to take advantage of the acquired knowledge, change is warranted. Typically, partners with low levels of knowledge utilization tend to be replaced in favor of others that could boost the utilization level of the entire network. Alternatively, actors with high levels of knowledge utilization might themselves depart their current network and move to more promising networks, where they believe they can better utilize their knowledge. Either way, the structure of the current network changes by the departure of an actor. Hence, it comes with no surprise that knowledge utilization is a key factor that influence network change.

Overall, the current study contributes to the literature in multiple ways. Drawing from the RBT, the study increases our understanding of dynamic networks and what might drive changes in network structure. Moreover, the study contributes to the knowledge literature by examining how knowledge utilization of current networks influences their structure in following periods. The study also responds to calls that encourage the application of network theory to study teams (Fewell et al, 2012; Katz et

al, 2004), and to calls that advocate the use of sports data to study organizational phenomena (Day et al, 2012). The study does so by employing network theory to study changes in basketball teams. Thus, it contributes to a recent trend that uses sports data in network-related research (e.g. Fewell et al, 2012), going beyond the traditional areas of human resources (e.g. Bloom, 1991; Wright et al, 1995) or RBT (e.g. Berman et al, 2002).

### 2.5.1: Limitations and Future Research

Although the study provides some insights that contribute to the literature, there are some limitations that should be noted. First, while previous research has shown the suitability of sports data to examine organizational phenomena, one should be cautious when generalizing the findings of this study to other industries. That being said, the NBA is an appropriate setting to examine network theory and knowledge-related studies. NBA players rely on each other on the court in a network-like structure (Berman et al, 2002), and with their skills, they precisely mirror the role of knowledge workers (Polanyi, 1969) that have been previously employed in studies involving network and knowledge (e.g. McFadyen et al, 2009).

Another limitation that should be mentioned is about other factors that I have not controlled for in this study. Specifically, there might be some factors that affected players' decisions to move to other teams beyond the factors I controlled for in the present study. To illustrate, players sometimes change their teams due to family-related reasons that have nothing to do with their ability to use their knowledge or any environmental circumstances surrounding their teams. For instance, before the 2007-



2008 season, Derek Fisher of the Utah Jazz asked his team to release him of his contract to join a team in a city where medical treatment is available for his daughter. I could not control for such factors in this study. Nevertheless, such factors are rare and should not have a significant impact on the findings.

Future research is needed to further advance the dynamic theory of networks. For instance, researchers could tell us more about the consequences of network change, as this study and other recent ones have solely focused on some antecedents of network change (e.g. Ozmel, Reuer, & Gulati, 2013; Cannella & McFadyen, forthcoming). Ample research has studied the consequences of several network features, but the majority of them assumed a static nature of networks (e.g. Ahuja, 2000; Schilling & Phelps, 2007, Tsai, 2001, Wang et al, 2014). Hence, interested scholars could investigate the consequences of frequent changes in network structures. Sytch and Tatarynowicz (2014) studied the impact of actors' mobility among network communities, which represents a start in this direction, but more research is still needed.

Network theorist who study knowledge-related issues can also explain the relationships between network dynamics and other knowledge features. In this study, I examined knowledge utilization as a predictor of network change. Previously, Cannella and McFadyen (forthcoming) explored the role of knowledge creation in network dynamics among knowledge workers, and Sytch and Tatarynowicz (2014) focused on network dynamics and invention. Others can tell us more about how concepts such as knowledge transfer, knowledge integration, or knowledge decomposition interplay with network dynamics. For example, scholars can further expand the domain of network dynamics to areas out of knowledge-related areas such as growth or survival.

Another interesting area for future research is to continue the use of sports data in organizational research. While a plethora of research has used such data, the number of sports-based research is still relatively small. Interestingly, most of the research has focused on issues related to human resource practices (e.g. Bloom, 1991; Wright et al, 1995), managerial succession (e.g. Rowe et al, 2005), or RBT (e.g. Berman et al, 2002). Other areas of organizational research could also benefit from sports data, including areas that employ network or institutional theories, among others.

## 2.6: Conclusion

Along with the research contribution, the study offers some helpful insights for managers. Particularly, because the basketball setting employed in this study resembles tasks usually performed in contemporary firms (Katz, 2001), the findings are more generalizable and insightful to start-ups and small/medium sized firms (Fonti & Maoret, forthcoming). For example, the findings suggest that while organizations might occasionally prefer to change their existing relationships, such decisions are partially limited by the resources organizations possess. Thus, managers are advised to balance between the desire to indulge in new collaborations, on one hand, and the need to manage their resources wisely, on the other hand. Also, the findings suggest that when organizations are not effectively benefiting from their current structure, they are more likely to seek new collaborations. Likewise, when organizations themselves are not helpful, their partners might look for more rewarding collaborations with other partners. Therefore, as they expect to benefit from their partners, organizations should also strive to provide positive contributions to their partners in order for the relationships to survive.

## Chapter 3:

### Network Characteristics and the Value of Knowledge Created in Developing Countries

#### 3.1: Introduction

Ever since theories of knowledge creation have emerged (e.g. Grant, 1996; Kogut & Zander, 1996; Nonaka, 1994), research on the topic has been increasing (Phelps et al., 2012). Specifically, scholars have employed network theory to examine the impact of various social capital and network-related features on the creation of new knowledge (e.g. McFadyen & Cannella, 2004; McFadyen et al., 2009; Perry-Smith, 2006; Schilling & Phelps, 2007). While there is a significant body of research on the interaction of knowledge creation and network theory, few studies have focused on how networks impact the value of newly created knowledge (see McFadyen & Cannella, 2004 as an exception). Importantly, such research is lacking when it comes to examining the value of new knowledge created in developing countries.

It is paramount to study knowledge creation in developing countries for two main reasons. First, the majority of studies on knowledge creation have focused on developed countries. Therefore, it is ideal to conduct a knowledge creation study on developing countries in order to test the generalizability of previous findings (Chua, forthcoming; Kotabe et al, 2007). Second, research asserts that new and advanced knowledge is more likely to be created in developed countries (Prahalad, 2005). Thus, it is important to examine ways by which valuable knowledge could be created in developing countries. It

is also important to study the value of created knowledge, given that not all knowledge has the same scientific and economic value (Hall et al, 2005; Trajtenberg, 1990).

Thus, some interesting questions need to be further addressed. For example, what factors could contribute to creating knowledge of high value? Specifically, how can developing countries, given their limited access to advanced knowledge, create new knowledge of high value? Utilizing network theory, the current paper attempts to contribute to the answer of the aforementioned questions by examining how some characteristics of networks of knowledge workers generally affect the value of created knowledge, and especially those created in developing countries. Using patents data, the current paper particularly aims to examine the impacts of network size and network diversity on knowledge creation value (figure 1). Following earlier studies, I refer to networks as sets of knowledge workers and the interpersonal relationships among those knowledge workers (Bourdieu, 1986; Burt, 1992; McFadyen & Cannella, 2004; McFadyen & Cannella, forthcoming; Nahapiet & Ghoshal, 1998; Phelps et al, 2012). I define knowledge creation as the creation of new knowledge that has not been known previously (Arrow, 1962; McFadyen & Cannella, 2004; Nonaka, 1994; Schumpeter, 1934).

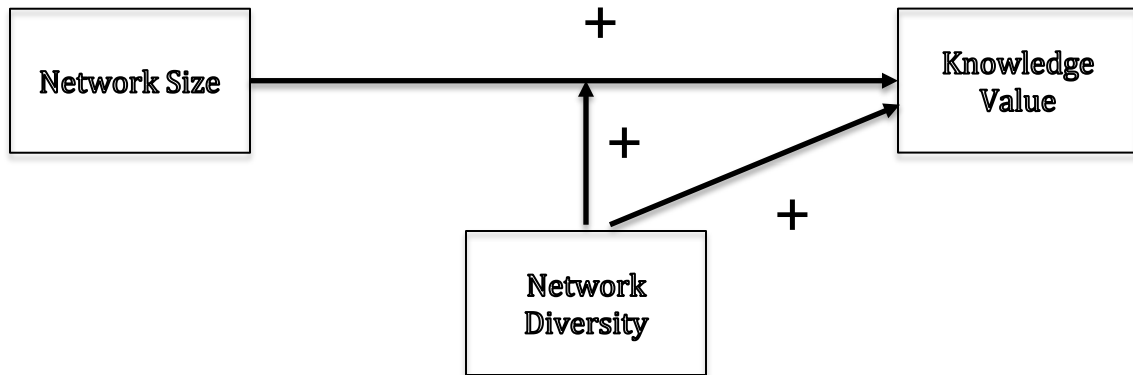


Figure 3-1: The impact of network size and network diversity on knowledge value

Applying network theory to study teams and small groups is widely used in the literature (Katz et al, 2004; Perry-Smith & Shalley, 2014; Sparrowe, Liden, Wayne, & Kraimer, 2005). For instance, previous studies have used social networks analysis to investigate how demographic diversity among R&D teams affect their productivity (Reagans & Zuckerman, 2001). Fewell et al (2012) built on it to study the offensive strategies of basketball teams. Rather than looking at networks' external ties (i.e. ties with others outside the focal network), the focus of this paper is on networks' internal ties (i.e. ties among the actors of the focal network). Overall, studying groups' internal ties through network analysis seems ideal for the examination of a knowledge worker's bounded relationships and the relationships' impact on the value of created knowledge.

The current paper is different than previous studies in multiple ways. First, unlike

the majority of research that used patents data of developed countries to examine various features of networks (e.g. Ahuja, 2000; Fleming, Mingo, & Chen, 2007; Kotabe et al, 2007; Nerkar & Paruchuri, 2005; Roper & Hewitt-Dundas, 2015), the present paper uses patents data of a developing country to assess the value of created knowledge and how it is affected by some network characteristics. In fact, it has been suggested that organizations in developing countries tend to collaborate with partners from developed countries to acquire stronger resources such as new knowledge (Hitt, Dacin, Levitas, Arregle, & Borza, 2000). Therefore, an examination of patents of developing countries seems warranted since characteristics of knowledge and knowledge workers in such countries are likely to be different than those in developed countries, and because such examination should be helpful in addressing generalizability issues (Chua, forthcoming; Kotabe et al, 2007).

Second, while Singh and Fleming (2010) studied the difference between lone inventors and teams of inventors and how they create knowledge of different values, the current paper proposes a linear positive relationship between network members and value of created knowledge. Specifically, the paper suggests that networks of knowledge workers with more members are predicted to create more valuable knowledge than those with fewer members. The paper also differs from Taylor and Greve (2006), who examined the relationship between number of creators and the financial performance of comic books. In particular, Taylor and Greve (2006) predicted that high numbers of creators are associated with extreme, both positive and negative, financial outcomes. Instead, the current paper focuses on the scientific value of the created knowledge,

regardless of whether the knowledge was converted into a product and its potential success of that product. In other words, while slightly different, the paper builds on Singh and Fleming (2010), suggesting that when more knowledge workers are involved, the value of created knowledge tends to increase accordingly. Using logistic regression models, Singh and Fleming (2010) found that teams are more likely to generate breakthrough inventions than lone inventors. In this paper, I suggest a linear relationship between the size of knowledge workers (inventors) and the value of the knowledge they create. Importantly, I use a sample from a developing country to provide a different context and to assess the generalizability of the disadvantages of lone inventors as found by Singh and Fleming (2010), given the different characteristics between developed and developing countries and the type of knowledge each possesses (Prahalad, 2005).

Third, while relatively close, the paper is different than McFadyen and Cannella (2004) in that it focuses on the size of a team of knowledge workers currently involved in creating a focal knowledge, instead of the number of relationships an individual scientist has had in the past. In other words, the two studies have different levels of analyses. While McFadyen and Cannella (2004) focused on an ego's network, the current paper examines the impact of network size at the network level. Also, the two studies employ different sets of data. That is, McFadyen & Cannella (2004) uses publications of biomedical scientists associated with two U.S. universities, while we were interested in the amount of knowledge created, the current paper uses patents data of knowledge workers from a developing country (Saudi Arabia). Finally, It should be noted also that McFadyen and Cannella (2004) used the Institute of Scientific Information's impact factor to assess

knowledge creation, while the present paper employs patents data to measure the value of knowledge creation. the paper also differs from Ahuja (2000), who sought to compare between direct and indirect ties and their impact on innovation outputs.

Overall, employing network theory and building on arguments from the knowledge literature, the paper seeks to suggest network characteristics that foster the creation of valuable knowledge for networks of knowledge workers from developing countries. It aims to broaden the application of network theory in the knowledge literature to include contexts different from what prior studies have focused on.

The rest of the paper is structured as follows. In the next section, I discuss knowledge creation in developing countries and provide arguments on how network size and network diversity predict the value of created knowledge. Then, I discuss the methodology used in this study, explaining the data collection process and all the variables, before presenting the results. Finally, the paper ends with the discussion and the conclusion sections.

## 3.2: Theoretical Background and Hypotheses Development

### 3.2.1: The Value of Created Knowledge in Developing Countries

Research asserts that knowledge resides within individuals (Polanyi, 1966), and that individuals interact with others and go through experiences that eventually enable them to create new knowledge (McFadyen et al, 2009; Nonaka, 1994; Polanyi, 1966). The creation of new knowledge comes about via combining existing knowledge



(Fleming, 2001; Nelson & Winter, 1982; Nonaka, 1994; Rosenkopf & Nerkar, 2001; Schumpeter, 1934). Thus, social interaction among knowledge workers is significant in knowledge creation (Kogut & Zander, 1992; 1996; McFadyen & Cannella, 2004; McFadyen et al, 2009; Nonaka, 1994).

While it is important to study what factors contribute to the amount of knowledge creation (McFadyen & Cannella, 2004; Phelps et al, 2012), I argue that it is equally important to focus on the value of created knowledge (e.g. Singh & Fleming, 2010). Knowledge does not have equal scientific and economic values, as some tend to be more valuable and contribute more to economic success (Hall et al, 2005). Previous studies have examined different aspects of creating knowledge of high value. Following Trajtenberg (1990) in using patents citations to measure the impact of new knowledge, Singh and Fleming (2010) have examined how the value of created knowledge differs between lone and team of inventors. On the other hand, Harhoff et al (1999) have shown that some patents (new knowledge) are more likely to get renewed than others because of their value to the inventor. Studies have also examined the relationships between the importance of newly created knowledge and inventors' ability to combine existing knowledge (Fleming, 2001; Nerkar, 2003; Rosenkopf & Nerkar, 2001), while others examined how the centrality of R&D teams predicts the impact of the new knowledge they create (Argyres & Silverman, 2004). Additionally, Albert, Avery, Narin, and McAllister (1991) suggest that experts evaluate organizations with more valuable knowledge more favorably than those with less valuable knowledge.

The assumptions of bounded rationality suggest that individuals are limited in

what they know (March & Simon, 1958, March 1991; Nelson & Winter 1982).

Consequently, individuals tend to look for others to acquire needed information out of necessity (Oliver, 1990). The acquisition of knowledge from external sources, when combined with existing knowledge, leads to the creation of new knowledge (Ahuja & Katila, 2001; Fleming, 2001; Nelson & Winter, 1982; Rosenkopf & Nerkar, 2001).

Importantly, because knowledge workers in developing countries usually lack access to new knowledge, resource-dependence theory (Pfeffer & Salancik, 1978) suggests that it is paramount important for them to form relationships with others from developed countries to possess such privilege.

To illustrate, research on international business posits that countries have unique location-specific knowledge (Alcacer & Chung, 2007; Almeida & Phene, 2004; Cantwell, 2009; Mudambi, 2008). Therefore, for knowledge workers, relationships with international partners present an opportunity to access unique and new knowledge (Chung & Alcacer, 2002; Dyer & Singh, 1998; Stuart & Podolny, 1996). In fact, Lavie and Miller (2008) suggest that relationships with international partners have an advantage when compared to relationships with domestic partners in that the former grants the focal unit an access to diverse knowledge. More importantly, research shows that “upstream relationships” (Eisenhardt & Schoonhoven, 1996), as in the case between knowledge workers in developing and those in developed countries, provide knowledge workers in developing countries with the latest knowledge and technologies that do not exist in their home country (Prahalad, 2005). Knowledge workers can then combine knowledge acquired from international partners with their own to create new knowledge of high

value (Ahuja & Katila, 2001; Ahuja & Lampert, 2001; Fleming, 2001).

Therefore, I argue that for knowledge workers from developing countries, building a network of knowledge workers including actors from developed countries, should increase the networks' chances of creating knowledge of high value. In the next sections, I discuss why network size and network diversity should influence the creation of valuable knowledge. Further, I provide specific arguments on why such characteristics are especially important for creating valuable knowledge in developing countries.

### 3.2.2: Network Size

Previous studies have found several benefits associated with large networks, such as better performance (e.g. Collins & Clark, 2003), more raised capital in IPOs (e.g. Deeds, DeCarolis, & Coombs, 1999), and network growth (Demirkan, Deeds, Demirkan, 2013). As for knowledge, networks of relationships are valuable resources for members to acquire, learn, and share knowledge (Bourdieu, 1986; Nahapiet & Ghoshal, 1998; Powell et al., 1996). They facilitate the social interactions needed by knowledge workers to eventually create new knowledge (Nonaka, 1994). Research shows that the number of relationships an actor maintains has a positive (Ahuja, 2000) or a curvilinear (McFadyen & Cannella, 2004) influence on knowledge creation. However, we know little about how the size of a network of knowledge workers affects the value, not the amount, of created knowledge.

Previous studies posit that network size is positively related to networks' ability to recombine existing knowledge (Schilling & Phelps, 2007). It has also been suggested that

new knowledge created by a team is more likely to be a breakthrough than one created by a lone knowledge worker (Fleming & Singh, 2010). In this paper, building on what Singh and Fleming (2010) found, I further argue that networks of knowledge workers in general, and especially from developing countries have more chance at creating valuable knowledge when more actors are involved. That is, I predict a network of four knowledge workers, for example, to be more likely to create valuable knowledge than a group of two knowledge workers.

First, a network of knowledge workers have more chance of creating valuable knowledge because novel ideas are more likely to be generated when different ideas are combined (Fleming, 2001; Schumpeter, 1934; Smith et al., 2005; Uzzi & Spiro, 2005). Unlike a single knowledge worker, networks of knowledge workers are predicted to generate more ideas. Then, the identification of novel ideas and the selection process tend to be more rigorous, due to the multiple filters that ideas go through when discussed among several individuals (Singh & Fleming, 2010; Fleming et al, 2007). Those ideas are then expected to be evaluated more thoroughly than ideas generated, selected, and evaluated by a single knowledge worker, due to the unique cognitive abilities and values of each knowledge worker (Singh & Fleming, 2010; Fleming et al, 2007; Hambrick, 1984). In short, individual knowledge workers, regardless of their expertise, are constrained by bounded-rationality (March & Simon 1958, March 1991). Generally, they find it hard to go alone through the complex process of identifying, selecting, and evaluating ideas in order to create new knowledge at the same level of a network of several members.

Second, as stated above, combining existing knowledge leads to the creation of new ones. The possibility of having diverse knowledge increases with larger networks (Burt, 1992; Demirkan et al, 2013). Because knowledge workers have different areas of specialties and their own knowledge stock (McFadyen & Cannella, 2004; Smith et al, 2005), they bring unique aspects to the process of knowledge creation. Thus, the pool of knowledge available to a network of knowledge workers is expected to be larger and more diverse than that of a lone worker. Therefore, larger networks are able to come up with ample combinations of existing knowledge, and eventually more likely to create valuable knowledge (Fleming, 2001).

Third, from an evolutionary perspective, a valuable knowledge is one that has an impact on future ones. In other words, knowledge is said to be of high value when it has an influence on the creation of new ones (Fleming, 2001). From a social point of view, larger networks allow for more “reach” of created knowledge. That is, because each knowledge worker contributing to the new knowledge is expected to have his own social network outside of the one creating the focal knowledge, the newly created knowledge is more likely to diffuse than that created by a single knowledge worker (Singh & Fleming; 2010; Singh, 2005). Put differently, knowledge created by larger networks are more likely to be identified and adopted by outsiders. When knowledge is widely spread, there is a higher chance that it gets recognized by another knowledge worker, who might in turn absorb it and combine it with his own existing knowledge to eventually create a new one.

Forming larger networks for knowledge workers might be more crucial for knowledge workers in developing countries due to their limited access to technology and new knowledge (Prahalad, 2005). Thus, more members in the network could provide an opportunity for learning about new knowledge or technology via the external ties that each knowledge worker has outside the focal network (Powell et al, 1996). For instance, knowledge worker (A) might be familiar with a certain technology that he learned while studying abroad, while knowledge worker (B), on the other hand, could bring his expertise of another technology that he acquired from previous collaborations with international knowledge workers. Hence, while generally knowledge workers of a developing country might be unfamiliar with certain knowledge, the cumulative knowledge of all members might make it easier for them collectively to possess a technology they need in their knowledge creation process.

One could argue that there are negative outcomes of large networks, as posited by previous studies (e.g. McFadyen & Cannella, 2004). However, those negative outcomes are mainly related to the cost of maintaining relationships within the network (Adler & Kwon, 2002; Burt, 1992; Hansen; 1999), which does not necessarily affect the knowledge value. The focus in this study is on the value of the created knowledge, regardless of how much it costs to be created. In other words, I focus on the final outcome, regardless of the process of reaching it.

To summarize, the aforementioned arguments suggest that knowledge created by larger networks should have more value because it is likely to be created after a rigorous

process of idea generation, selection, and evaluation. Additionally, combining the efforts and expertise of several knowledge workers could enable them to acquire more knowledge that, when working individually, they would not be able to access. Acquiring such knowledge would provide them with the opportunity to combine diverse knowledge in order to create new one (Fleming, 2001). Finally, knowledge created by larger networks is expected to have more reach than one created by single knowledge workers. Recipients of such knowledge could combine it with their own stock of knowledge for future knowledge creations. Thus, for knowledge workers in general, and especially those in developing countries, I suggest that forming larger networks is more likely to produce valuable knowledge.

*Hypothesis 1: There is a positive relationship between the size of networks of knowledge workers and the value of the knowledge they create.*

### 3.2.3: Network Diversity

The benefits of having a diverse network have been widely discussed in the literature (e.g. Ahuja, 2000; Burt, 1992; Granovetter, 1973; Reagans & Zuckerman, 2001; Smith et al, 2005). For example, the theory of structural holes (Burt, 1992) suggests that, unlike having dense networks, having structural holes in an actor's network enables the actor to receive diverse information from sparse partners. Research on creativity and innovation has also supported the idea that combining diverse information leads to novel inventions (e.g. Ahuja, 2000; Fleming, 2001; Perry-Smith & Shalley, 2014; Schilling & Phelps, 2007; Uzzi & Spiro, 2005). For instance, Ahuja (2000) found that indirect ties

provide actors with diverse information that they can use to increase their innovativeness, while Reagans and Zuckerman (2001) found that diversity in R&D teams positively influences their productivity. A more recent study on team creativity found that the ties team members have with diverse outsiders tend to increase their creativity (Perry-Smith & Shalley, 2014).

In the present paper, I argue that knowledge workers can create more valuable knowledge by increasing the diversity of their networks. Specifically, I predict that for knowledge workers in developing countries, when more knowledge workers from developed countries are involved in the knowledge creation process, the created knowledge will have more value.

The cognitive dimension of social capital (Carnabuci & Diószegi, 2015; Nahapiet & Ghoshal, 1998) focuses on the cognitive aspects of network actors. The cognitive dimension goes beyond the individual's surface characteristics such as demographics; instead, it focuses on deep-level characteristics such as backgrounds, values, skills, and knowledge (Harrison, Price, & Bell, 1998). In networks, while some aspects of cognitive characteristics, such as shared language and codes among knowledge workers, make communication a bit easier, heterogeneity among knowledge workers in deep-level characteristics tends to inspire the creation of novel knowledge (Carnabuci & Diószegi, 2015; Fleming, 2001; Nahapiet & Ghoshal, 1998; Schilling & Phelps, 2007). For example, when combined, the knowledge stock of an engineer and that of a natural scientist is more likely to create valuable knowledge than the combination of knowledge



stocks of two engineers. The reason is that, unlike the latter, the former combination allows knowledge workers to bring diverse skills and knowledge to the situation, and also enables them to evaluate ideas from different point of views (Fleming, 2001).

In the case of knowledge workers from developing countries, forming relationships with others from developed countries introduces different perspectives to the network (Chua, forthcoming). Because they come from a different background and going through different experiences, knowledge workers from developed countries should bring a different point of view to the process of generating, selecting, and evaluating ideas in networks. Importantly, having knowledge workers from developed countries in the network will provide their counterparts from developing countries with access to an array of knowledge that would not have been available if knowledge workers from developed countries were not included in the network (Alcacer & Chung, 2007; Almeida & Phene, 2004; Cantwell, 2009; Prahalad, 2005). In other words, one way for knowledge workers in developing countries to “catch up” with advanced knowledge created in developed countries is by having access to the location-specific knowledge activities performed in developed countries (Cantwell, 2009; Mudambi, 2008). As suggested by resource-dependence theory (Pfeffer & Salancik, 1978), forming relationships with resource-holders is one way to have access to crucial resources, such as knowledge. Thus, having more knowledge workers from developed countries in the network enables the network to possess up-to-date knowledge that can be combined with the stock of knowledge workers from developing countries to create new knowledge (Fleming, 2001; Schumpeter, 1934).

*Hypothesis 2: For networks of knowledge workers in developing countries, increasing network diversity by adding actors from developed countries has a positive impact on the value of created knowledge.*

That being said, an argument could be made that the impacts of network size and that of network diversity on the value of created knowledge are interrelated. To illustrate, a large network of knowledge workers without much diversity, while possibly providing distinct specialties or expertise to the network, would lack the different backgrounds or values that usually come with interacting with knowledge workers from other countries. For knowledge workers from developing countries, such a network might possess advanced knowledge, especially if some members have studied or worked abroad (Godart Maddux, Shipilov, & Galinsky, 2015; Maddux & Galinsky, 2009); however, a continuous and an up-to-date access to new knowledge would be still lacking. Thus, the network would be missing a crucial resource that could influence the value of the knowledge the network is creating.

Likewise, a diverse but small network might have the diversity element, but the number of members might be insufficient to account for all aspects needed in the knowledge creation process. For example, to create a very complex knowledge that requires experts in several areas, a network of two knowledge workers might not be enough to cover all related areas. Thus, I argue that there is a positive interaction between network size and network diversity as they relate to the value of knowledge creation.

*Hypothesis 3: The positive relationship between network size and the value of created*

*knowledge will increase as the degree of network diversity increases.*

### 3.3: Methods

#### 3.3.1: Sample

In order to test the hypotheses of the current study, the sample has to be from a developing country that has some knowledge creation activities. Therefore, I elected to examine the value of knowledge created by networks of knowledge workers from Saudi Arabia. Saudi Arabia is an emerging country in terms of knowledge creation and the government, with participation from multiple industries, has launched several initiatives to increase knowledge creation in the last several years. In fact, the World Economics Forum (WEF) report on competitiveness for 2015-2016 ranks Saudi Arabia as 34<sup>th</sup> among 140 countries included in the report in terms of innovation activities. This acknowledges the increasing emphasis on innovation by the country, while showing that it is still far from competing with more developed countries. I used data on patents granted to Saudi assignees by the United States Patent and Trademark Office (USPTO). Although Saudi Arabia has its own patent office, I chose the USPTO instead for multiple reasons.

First, unlike data from the Saudi Arabian patent office (SPO), data from the USPTO is highly used in the literature of knowledge creation and innovation (e.g. Ahuja, 2000; Funk, 2014; Hall et al., 2005; Schilling & Phelps, 2007; Singh & Fleming, 2010; Trajtenberg, 1990). Particularly, it has been commonly used for patents-related studies in international contexts (e.g. Ahuja, 2000; Stuart, 1998). Therefore, patents registered at

the USPTO are expected to have more exposure and are more likely to get cited. Second, the USPTO database provides rich and longitudinal information, including data on inventors who created the knowledge, patents citations, the date on which the patent was granted, and classes under which the patent falls. Such information allows for measuring several variables related to the study. Finally, the USPTO provides the opportunity to collect large data from different industries, which increases the statistical power of the analysis and the generalizability of the results (Singh & Fleming, 2010).

The USPTO database records data from as early as 1790. However, the first patent assigned to a Saudi-based inventor was granted in 1983. Therefore, my final data includes patents from 1983-2009. Following previous studies, the decision to stop in 2009 is to allow time for created knowledge to diffuse and because knowledge tends to lose value after five years (Singh, 2005). The final dataset used in the analysis contains 228 patents.

### 3.3.2: Dependent Variable

*3.3.2.1: Knowledge value.* Knowledge value is a reflection of the knowledge's impact, importance, and its contribution to future knowledge (Albert et al, 1991; Nerkar, 2003; Singh, Fleming, 2010; Trajtenberg, 1990). Patents, as an indication of inventions, provide a validated measure of knowledge creation (Schilling & Phelps, 2007). To measure knowledge value, I follow previous studies in using patents' forward citations as a proxy for the value of created knowledge (e.g. Albert et al, 1991; Capaldo, Lavie, Petruzzelli, forthcoming; Gittelman & Kogut, 2003; Hall et al, 2005; Trajtenberg, 1990).

In this paper, I examined every patent granted to a Saudi assignee between 1983-2009 and counted how many citations every one of them has received. Previous studies have raised some concerns about using patents data (e.g. Fleming, 2001; Schiling & Phelps, 2007; Singh & Fleming, 2010), especially those related to unpatented inventions due to strategic decisions by firms. However, this concern does not apply to the current study because by using patents, the focus here is not on networks' ability to innovate or create new knowledge. Rather, I focus on already created knowledge to test their value.

### 3.3.3: Independent Variables

*3.3.3.1: Network size.* I measured network size by counting how many inventors were involved in creating the knowledge associated with the patent. Dealing with the team of inventors from a social network perspective (Katz et al, 2004), each inventor is an actor in the network. Thus, the total number of members represents the size of the network. It should be noted again that the unit of analysis in this paper is at the network level; not ego networks as in previous studies (e.g. McFadyen & Cannella, 2004).

*3.3.3.2: Network diversity.* One element of diversity is related to the values and backgrounds of the individual. The cognitive dimension of social capital (Nahapiet & Ghoshal, 1998) asserts that each actor is influenced by its own values, culture, and background. Thus, to capture diversity in this paper, I found where each inventor was located at the time of application, and counted how many inventors were non-Saudis. Then, I divided the number of non-Saudi inventors by the total number of inventors to get a ratio of non-Saudi inventors who contributed to the knowledge creation. The USPTO

provides information about all inventors and their country at the time the patent is applied for. The country where an inventor was born and raised should significantly influence the inventor's values and norms (Leung, Maddox, Galinsky, Chiu, 2008; Perry-Smith & Shalley, 2014), and should reflect the quality of the education the inventor has received. It should be noted that all non-Saudi inventors were from developed countries, mainly from the U.S.

Obviously, some western inventors, for example, might have been working in Saudi Arabia at the time the inventors applied for the patent. Likewise, a Saudi inventor might have been abroad at the time of patent application. To account for such cases, I looked at each inventor's biography in his organization's website or at websites like *LinkedIn.com*, when available. For individuals working in organizations where access to human resource personnel was available, I contacted the organization to confirm the country of origin of each inventor. As a final robust check, I examined first names of inventors to recognize names that are not common for Saudi individuals. I compared those names with names that are not allowed by the Saudi government because they are either religiously inappropriate or not Arabic-based. When all previous steps did not provide definitive information on the country of origin for an inventor, I went with the country listed by the USPTO.

#### 3.3.4: Control Variables

Several factors could influence the value of created knowledge. To account for the possibility that older patents are more likely to get cited than newer ones (Nerkar &

Paruchuri, 2005), I included *patent age* as a control variable. Patent age was calculated by measuring the time elapsed since the patent was granted by the USPTO. I also included the *square term of patent age* to account for the assumption that patents' importance may decrease with time. Additionally, based on the classification system used by the USPTO, patents are classified into different technological classes and subclasses. Consistent with others (e.g. Fleming et al, 2007), the *number of classes* a patent was classified into was included in the model to account for the scope of the patent, as patents classified into more classes are expected to have more value. Previous research suggests that the scope of a patent does, indeed, affect the patent's value (Lanjouw & Schankerman, 2001).

Other important control variables were also included in the model. I controlled for the *number of cited patents*. Patents that cite more prior art could belong to crowded classes, have more impact compared to other patents, and tend to be cited more heavily (Fleming, 2001). The *number of academic references* was also included as a control variable to capture the fact that patents that cite more academic references are usually built on more fundamental knowledge (Nerkar & Paruchuri, 2005). Research also posits that academic references allow for faster knowledge diffusion (Fleming et al, 2007; Sorenson & Fleming, 2004). As suggested in previous studies (e.g. McFadyen & Cannella, 2004), the time network members have spent together is more likely to influence knowledge creation. Hence, I include *tie strength*, operationalized as the number of previous interactions between at least two members of the network, in the model as a control variable. Because network members tend to develop homogenous

knowledge stocks after long-term relationships and negatively affect the creation of new knowledge (McFadyen & Cannella, 2004), I also controlled for *the squared term of tie strength*.

Another important control variable is the *age of prior art*. The variable measures the age of the patents cited by the focal patent, and it is intended to control for the assumption that older knowledge is more known and is less fertile (Fleming et al, 2007). To calculate the variable, I followed Fleming et al's procedure that takes the average of the patents' numbers that the focal patent cites as prior art and then divide it by one million to avoid extremely small coefficients. *Self-citations* were also accounted for by including a variable that takes the value of 1 if a patent is self-cited by at least one of the inventors, and 0 otherwise. Self-citations could reflect a bias by one of the inventors, a confidence of inventors' own knowledge (Nerkar & Paruchuri, 2005), or just because individuals are prone to local search (Rosenkopf & Nerkar 2001).

As a proxy for the importance of the patents, and consistent with previous studies (e.g. Nerkar & Paruchuri, 2005), I controlled for the *number of claims*. I also controlled for the time that it took for the patent to be granted (i.e. *time to grant*), as patents that take longer to be granted tend to be more complex (Nerkar & Paruchuri, 2005). I calculated the variable as the difference between the year the patent was granted and the year it was applied for, as provided by the USPTO. Finally, I included *years* and *type of assignees* (i.e. individuals, universities, or firms) dummies to control for any variation related to them that could affect citation patterns. Research suggests that patents assigned to



organizations are more likely to be valuable (Singh & Fleming, 2010), and that older patents lose value with time (Singh, 2005). Table (3-1) shows all variables included in the analysis and their respective measures.

Table 3-1: Description of variables

| Variable          | Type                        | Description   | Measure   |
|-------------------|-----------------------------|---|---|
| Knowledge Value   | <i>Dependent variable</i>   | The scientific value of created knowledge                                     | Forward citations of the focal patents  |
| Network Size      | <i>Independent variable</i> | The size of the network of knowledge workers                                  | Number of inventors involved in creating the knowledge                                |
| Network Diversity | <i>Independent variable</i> | Ratio of knowledge workers from developed countries in the network            | Number of non-Saudi inventors divided by the total number of inventors in the network |
| Patent Age        | <i>Control variable</i>     | Older patents are likely to have more citation                                | The time elapsed since the patent was granted by the USPTO                            |
| Patent Age ^2     | <i>Control variable</i>     | To account for the assumption that patents' importance may decrease with time | The square of the time elapsed since the patent was granted by the USPTO              |
| Time to Grant     | <i>Control variable</i>     | Patents that take longer to be granted tend to be more complex                | The year the patent was granted minus the year it was applied for                     |

|                           |                         |   |   |
|---------------------------|-------------------------|---|---|
| Number of subclasses      | <i>Control variable</i> | The different domains the patent are classified under   | The number of focal patent's classes  |
| Number of Cited Patents   | <i>Control variable</i> | Patents that cite more should be more cited   | Number of prior art cited by the focal patent   |
| Age of prior art          | <i>Control variable</i> | Older knowledge is more known and less likely to get cited by the focal patent                          | The average of the patents' numbers that the focal patent cites as prior art divided by one million |
| Number of Academic Ref    | <i>Control variable</i> | Patents citing more academic references are built on more fundamental knowledge and are diffused faster | Number of citations made by the focal patent to academic references                                 |
| Tie Strength              | <i>Control variable</i> | The time network members have spent together  | The number of previous interactions between at least two members of the network                     |
| Tie Strength <sup>2</sup> | <i>Control variable</i> | Network members tend to develop homogenous knowledge stocks after long-term relationships               | The square of the number of previous interactions between at least two members of the network       |

### 3.3.5: Analysis

Patents represent a count variable that takes on non-negative values only. Accordingly, the distribution of errors in this study is skewed and heteroscedastic. Hence, the linear regression model, which assumes a normal and homoscedastic distribution, is inadequate. While the Poisson regression approach seems appropriate, it would not be ideal for this study because patents data usually suffers from overdispersion (Hausman et al., 1984; Schilling & Phelps, 2007). In cases of overdispersion, the standard errors generally tend to be underestimated, which leads to high levels of significance (Cameron & Trivedi 1986). Therefore, I elected to use the negative binomial regression as an alternative approach (Long & Freese, 2006), which is common in patents-based studies (e.g. Schilling & Phelps, 2007; Srivastava & Gnyawali, 2011). Generally, the negative binomial model is a generalization of the Poisson model. However, it deals with overdispersion by incorporating an individual, unobserved effect into the conditional mean (Greene, 2000; Hausman et al. 1984).

### 3.4: Results

Table (3-1) provides descriptive statistics and correlations for the variables included in the models. I examined the data for assumptions of normality and multicollinearity. The dependent variable followed a negative binomial distribution, and all other variables approximated normal distributions. The maximum likelihood method employed in the study did not provide statistics such as variance inflation factors (VIFs) to check for multicollinearity. However, I examined the correlation metrics to check if

any variables were highly correlated. With the exception of the squared terms (i.e. patent age and tie strength), the matrix didn't show a significant problem that would affect the results, even when omitting some variables from the analysis. This suggests that multicollinearity was not an issue that affected the results of this study.

Table 3-2: Descriptive Statistics

| Variables          | Mean  | SD    | 1     | 2     | 3     | 4     | 5     | 6    | 7     | 8     | 9    | 10   | 11    | 12    | 13   |
|--------------------|-------|-------|-------|-------|-------|-------|-------|------|-------|-------|------|------|-------|-------|------|
| Knowledge Value    | 1.89  | 2.24  | 1.00  |       |       |       |       |      |       |       |      |      |       |       |      |
| Patent Age         | 11.25 | 5.21  | 0.10  | 1.00  |       |       |       |      |       |       |      |      |       |       |      |
| Patent Age ^2      | 153.6 | 167.8 | 0.06  | 0.97  | 1.00  |       |       |      |       |       |      |      |       |       |      |
| Time to Grant      | 2.50  | 1.21  | 0.07  | -0.36 | -0.30 | 1.00  |       |      |       |       |      |      |       |       |      |
| # Subclasses       | 5.73  | 8.35  | 0.18  | 0.02  | 0.01  | 0.04  | 1.00  |      |       |       |      |      |       |       |      |
| #Cited Patents     | 25.92 | 42.85 | -0.02 | -0.21 | -0.17 | -0.13 | -0.04 | 1.00 |       |       |      |      |       |       |      |
| Age of prior art   | 4.72  | 1.04  | 0.08  | -0.38 | -0.41 | 0.05  | 0.08  | 0.19 | 1.00  |       |      |      |       |       |      |
| #Academic Ref      | 2.02  | 4.41  | 0.27  | -0.05 | -0.02 | 0.14  | 0.10  | 0.25 | 0.01  | 1.00  |      |      |       |       |      |
| Tie Strength       | 1.77  | 4.04  | -0.03 | -0.02 | -0.04 | -0.17 | 0.00  | 0.35 | 0.12  | 0.01  | 1.00 |      |       |       |      |
| Tie Strength^2     | 19.37 | 96.83 | -0.07 | 0.04  | 0.02  | -0.11 | 0.00  | 0.13 | 0.04  | -0.01 | 0.87 | 1.00 |       |       |      |
| Network Size       | 2.42  | 1.45  | 0.16  | -0.04 | -0.10 | -0.04 | 0.04  | 0.09 | 0.17  | -0.12 | 0.39 | 0.21 | 1.00  |       |      |
| Network Diversity  | 0.72  | 0.38  | 0.15  | 0.04  | 0.03  | -0.07 | 0.12  | 0.18 | 0.19  | 0.05  | 0.18 | 0.12 | 0.10  | 1.00  |      |
| N.size*N.diversity | 0.06  | 0.51  | -0.20 | -0.09 | -0.09 | -0.09 | -0.07 | 0.07 | -0.07 | 0.00  | 0.07 | 0.08 | -0.16 | -0.46 | 1.00 |

The results of the negative binomial regression models are presented in Table (3-3). Model 1 represents the base model, in which only the control variables and the dependent variable are included. The independent variables were included in model 2, to test the direct effects of network size and network diversity on the value of created knowledge. Model 3 represents the full model, showing the interaction between network size and network diversity, which is the mean-centered multiplication of both variables.

Hypothesis 1 predicts that there is a positive relationship between network size and knowledge creation value. Model 2 shows that the coefficient for network size is positive and significant ( $\beta = 0.11, p < 0.05$ ), providing support for hypothesis 1. Hypothesis 2 suggests a positive relationship between network diversity among knowledge workers and the value of created knowledge. As shown in model 2, the results provide strong support for hypothesis 2, as the coefficient for network diversity is positive and significant ( $\beta = 0.49, p < 0.05$ ). Hypothesis 3 predicts that the positive relationship between network size and the value of created knowledge will increase as the degree of network diversity increases. Contrary to what I predicted, model 3 shows that the interaction of network size and network diversity is indeed significant, but in the opposite direction ( $\beta = -0.30, p > 0.05$ ). Hence, hypothesis 3 was not supported.

Table 3-3: The negative binomial models predicting knowledge value\*

| Variables              | Model 1             | Model 2            | Model 3            |
|------------------------|---------------------|--------------------|--------------------|
| Assignee (Individuals) | 0.08<br>(0.46)      | 0.09*<br>(0.45)    | 0.02*<br>(0.44)    |
| Assignee (Others)      | -0.09<br>(0.28)     | 0.15<br>(0.30)     | 0.12<br>(0.30)     |
| Self Citation          | -0.38<br>(0.28)     | -0.35<br>(0.19)    | -0.41*<br>(0.20)   |
| Patent Age             | 0.19**<br>(0.07)    | 0.16*<br>(0.06)    | 0.16*<br>(0.06)    |
| Patent Age ^2          | -0.004*<br>(0.002)  | -0.004*<br>(0.02)  | -0.004*<br>(0.002) |
| Time of Grant          | 0.10<br>(0.08)      | 0.08<br>(0.08)     | 0.07<br>(0.08)     |
| # Subclasses           | 0.02**<br>(0.006)   | 0.01*<br>(0.005)   | 0.01**<br>(0.005)  |
| #Cited Patents         | 0.00<br>(0.001)     | - 0.001<br>(0.001) | 0.00<br>(0.001)    |
| Age of prior art       | 0.19*<br>(0.09)     | 0.14<br>(0.09)     | 0.14<br>(0.09)     |
| #Academic Ref          | 0.04**<br>(0.01)    | 0.05**<br>(0.01)   | 0.05*<br>(0.01)    |
| Tie Strength           | 0.10*<br>(0.04)     | 0.43<br>(0.04)     | 0.05<br>(0.04)     |
| Tie Strength^2         | -0.007**<br>(0.002) | -0.005*<br>(0.002) | -0.005*<br>(0.002) |
| Network Size           |                     | 0.11*<br>(0.05)    | 0.08<br>(0.05)     |
| Network Diversity      |                     | 0.49*<br>(0.21)    | 0.31<br>(0.23)     |
| N.Size*N.Diversity     |                     |                    | -0.30*<br>(0.15)   |



|                     |         |         |         |
|---------------------|---------|---------|---------|
| Wald X <sup>2</sup> | 67.36   | 96.33   | 100.36  |
| Log-likelihood      | -405.88 | -401.73 | -400.02 |

---

\* All models are derived from a maximum-likelihood Poisson specification with robust standard errors (reported in parentheses). \* p <.05 , \*\* p < .01

As a robustness check, I ran the models using a conditional fixed-effects quasi-maximum-likelihood Poisson regression, which has been used in the literature as an alternative to the negative binomial regression (e.g. Funk, 2014). While the negative binomial regression is more suitable for this study, research suggests that the Poisson approach is less strict than the negative binomial in terms of distributional assumptions, and that it provides consistent estimates if the conditional mean is correctly specified (Gouriéroux et al., 1984). Additionally, I used the *vce (robust)* command in the STATA statistical package to control for any violations in the underlying assumptions (Cameron & Trivedi, 2009; Huber, 1967). The results of the Poisson models were similar to those of the negative binomial models. I also ran a model with the square of *network size* included to control for potential negative effects of large networks (McFadyen & Cannella, 2004). The variable was not significant and did not change the results.

### 3.5: Discussion

The purpose of this study was to examine if network size and network diversity increase the possibility for knowledge workers to create valuable new knowledge. A specific interest was to examine the relationships in developing countries, given the fact

that most knowledge-related studies are conducted on developed countries, and more importantly because developing countries do not have access to new and advanced knowledge. The results provided evidence that knowledge workers from developing countries can create new knowledge of high value by forming large and diverse networks. With every addition of a network member to the network, networks have more opportunities to add more information and expertise to the knowledge stock of the network. For knowledge workers in developing countries, large networks enable them to have more resources that can be used to access new knowledge that developing countries usually lack. Using data on Saudi Arabian-based patents, our findings supported the notion that network size positively influences the value of created knowledge.

The study also proposed that network diversity has a positive impact on knowledge creation value. In diverse networks, knowledge workers come from different backgrounds and have different values. Thus, ideas are evaluated from different points of view and knowledge creation is more novel (Fleming, 2001). More importantly, because new knowledge is more likely to exist in developed countries (Prahalad, 2005), the presence of knowledge workers from developed countries gives the network access to updated knowledge. When combining their own knowledge with that of knowledge workers from developed countries, knowledge workers from developing countries increase their chances of creating valuable knowledge. The results provided strong support for the idea that knowledge workers from developing countries are more likely to create valuable knowledge when their network is more diverse.

The paper also examined the interaction of network size and network diversity. I predicted a positive relationship where the positive impact of network size on knowledge creation value would increase with the increase of network diversity. The findings found a significant relationships but in the opposite direction. These results suggest that in cases of large networks of knowledge workers from developing countries, the chance of creating valuable knowledge would increase with less diversity among knowledge workers. On the other hand, the findings informed us that when the size of the network is small, more diversity is helpful for knowledge workers to create knowledge of high value. There are two possible explanations for this finding.

First, the communication among large numbers of knowledge workers could be difficult. Like I mentioned earlier in the paper, the cost of communication is not an issue in this study, since knowledge value is the dependent variable, not financial performance. That being said, other barriers could contribute to communication difficulties among knowledge workers, like geographic distances and language barriers, despite advanced technology that made communication much easier than in the past. Thus, while the addition of knowledge workers from developed countries in the network is significantly important, the ability to communicate among too many knowledge workers could make the benefit of such collaboration less impactful.

Second, with the increase of local knowledge workers from developing countries being educated in developed countries, a large number of such workers in the network could make up for the lack of knowledge workers from developed countries. That is, the

value that knowledge workers from developed countries bring to the network might be less necessary for the network to create valuable knowledge. As illustrated earlier, the main idea behind collaborating with knowledge workers from developed countries is to have access to new knowledge that usually does not exist in developing countries. However, such new knowledge could be acquired via formal education in developed countries or through frequent interactions with experts with more updated knowledge. Hence, as found in this study, the need for diversity might be less necessary in large networks. Generally, the finding of the interaction of network size and network diversity suggests that to overcome the absence of knowledge workers from developed countries, knowledge workers from developing countries could increase the possibility of creating valuable knowledge by increasing the number of local knowledge workers, especially those with formal education in, or regular interaction and contacts with, developed countries.

The study contributes to the literature in multiple ways. First, whereas most studies on network theory and knowledge creation focused on knowledge created in developed countries, the present study takes an international view by examining the relationships between network characteristics and the value of knowledge created by knowledge workers from developing countries. It is important to study knowledge creation in developing countries because countries have different location-specific knowledge (Almeida & Phene, 2004; Cantwell, 2009; Mudambi, 2008), and because new knowledge is more likely to be available in developed countries. Thus, the present paper advocates the expansion of network theory to study knowledge creation in developing

countries.

Second, rather than studying the impact of network size on the amount of created knowledge (e.g. McFadyen & Cannella, 2004), the current study focuses on the value of knowledge creation and how it would be influenced by the size of knowledge workers' network. Finally, the level of analysis in this study is at the network level, which departs from the common units of analyses of the majority of previous network research that examined knowledge creation at the individual (e.g. McFadyen et al, 2009) or organizational level (e.g. Schilling & Phelps, 2007).

### 3.5.1: Limitations and Future Research

While the study offers several contributions, some limitations are worth noting. First, while the paper studies the value of knowledge creation in developing countries, one should be cautious when generalizing the results of this study, given the different characteristics that distinguish Saudi Arabia from other developing countries. Saudi Arabia, as a wealthy country and a member of the group of twenty (G-20), is not a typical developing country that usually struggles economically. For example, knowledge workers from wealthy countries, especially those affiliated with large organizations, are more capable of networking with knowledge workers from developed countries. They are also more likely to be educated abroad than their counterparts from less-advantaged countries.

Another limitation that is typical in collaboration research is related to the process and dynamics of collaboration among knowledge workers. For instance, it is

usually difficult to assess the extent to which members are interacting or to know how much each member contributed. Unlike in scientific publications, where the order of co-authors tends to represent an author's contribution (McFadyen & Cannella, 2004), the order of co-inventors in patents does not necessarily reflect the inventors' contribution to the created knowledge. It is also hard to know when a collaboration started and whether the timing of collaboration has any impact on knowledge creation value (Singh & Fleming, 2010).

Future research on network theory and knowledge creation could conduct similar studies on other developing countries for broader generalizability. It would be interesting to see if the results of the current study are generalizable to other developing countries with lower economic status than Saudi Arabia. Scholars could also develop a framework of knowledge creation value that knowledge workers from developing countries could adopt to better understand the process of creating valuable knowledge.

### 3.6: Conclusion

Adopting network theory, the current paper sought to examine whether network size and network diversity could influence the ability of knowledge workers from developing countries to create valuable knowledge. Using patents data granted to Saudi assignees by the USPTO, the findings support the argument that network size and network diversity are positively related to knowledge creation value, while their interaction was not necessarily a significant contributor.

The findings should be of interest to knowledge workers and their managers in

general, and particularly to those from developing countries as they strive to create valuable knowledge. The findings of the current study posit that for knowledge workers, adding new members to their network could be beneficial in providing a potential access to new knowledge and in providing additional expertise to the network. Additionally, knowledge workers and their managers in developing countries should look for collaborations with others from developed countries to have access to new knowledge. Not only do knowledge workers provide new knowledge, but they also bring a different background and perspective to the network. As shown in this study, increasing the diversity of the network has a strong impact on creating valuable knowledge. In fact, according to the findings of the study, knowledge workers should also be aware that network diversity has a higher marginal impact on knowledge creation value than network size. That is, while adding members to the network is crucial, adding members from developed countries with different values and backgrounds seems to be more important.

## Chapter 4:

### Does Value Matter? An Examination of the Impact of Knowledge Value on Firm Performance and the Moderating Role of Knowledge Breadth

#### 4.1: Introduction

Resource-based theory asserts that knowledge is a critical resource for firms (Grant, 1996; Kogut & Zander, 1996). Therefore, knowledge creation, defined as the generation of new knowledge that did not exist before (Arrow, 1962; McFadyen & Cannella, 2004; Nonaka, 1994; Schumpeter, 1934), is essential for firms. Research on knowledge creation has been growing rapidly (Phelps et al., 2012), and the focus has varied from developing theories of knowledge creation (e.g. Grant, 1996; Kogut & Zander, 1996; Nonaka, 1994) to studies on factors that influence knowledge creation (e.g. McFadyen & Cannella, 2004; McFadyen, , 2009; Perry-Smith, 2006; Schilling & Phelps, 2007), and the impact of knowledge creation on firm performance.

Ample research on the impact of knowledge creation on firm performance used patents data to predict firm outcomes such as profit, sales, growth, and market value. However, the findings have been mixed and no consistent conclusion have been reached. For example, Artz et al (2010) found that the number of patents a firm owns is negatively associated with firm performance, measured as return on investment (ROI). On the other hand, other studies have found a positive relationships between knowledge creation and other measures of firms, such as sales and longevity (e.g. Ernst, 2001; Mann & Sager,



2007). Interestingly, other studies have found no significant relationship between knowledge creation and firm performance (e.g. Griliches et al, 1991). Another issue in the literature of knowledge creation and firm performance is that we know very little about how the value, not the amount, of created knowledge impact firms' financial performance. It is vital to empirically examine such a relationship due to the fact that knowledge does not have equal value (Albert et al, 1991; Nerkar & Paruchuri, 2005; Singh & Fleming, 2010; Trajtenberg, 1990).

Therefore, the current study seeks to contribute to the literature that focuses on the impact of knowledge creation on firm performance. Importantly, it attempts to assess whether firms would generate more revenue from knowledge of high value than from those of less value. In this paper, knowledge value is defined as knowledge's impact, importance, and contribution to future knowledge (Albert et al, 1991; Nerkar, 2003; Singh & Fleming, 2010; Trajtenberg, 1990). The study also examines how knowledge breadth moderates the aforementioned relationship, given the flexibility that broad knowledge tends to have compared to narrow knowledge (Leonard-Barton, 1995; Volberda, 1996). Figure (4-1) depicts the relationships examined in this study.

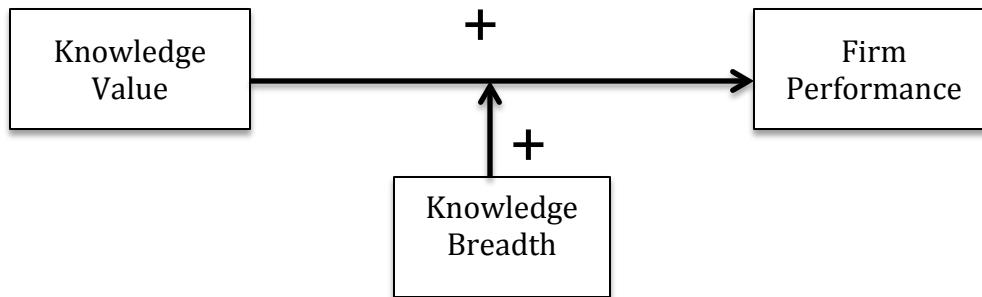


Figure 4-1: The impact of knowledge value on firm performance and the moderating role of knowledge breadth

Studying how the value of created knowledge influences firm performance is important because of the huge investments firms make in R&D as a way to grow and to hold a competitive advantage (DeCarolis & Deeds, 1999; Kogut & Zander, 1996). Large volumes of money are paid by firms to purchase and maintain research facilities, hire researchers, and provide proper funding to generate ideas and implement them all the way to the commercialization stage. Firms also invest heavily in purchasing valuable knowledge created by other firms, acknowledging how vital such knowledge could be from a strategic point of view. For example, according to official reports from Apple, the firm invested more than \$8 billion in R&D in 2015. Google, on their part, paid \$12.5 billion to acquire Motorola in 2011 (Roberts, 2014), mainly to own the knowledge (patents) that Motorola possessed. Taking on such costly investments, firms logically expect a profitable return on their investment (Artz et al., 2010). Revenue from valuable knowledge could be the result of direct utilization of created knowledge in the form of

commercialized products (Schumpeter, 1934; Teece, 1988), out-licensing or selling of knowledge to other firms (Moore, 2004; Sampat & Zeidonis, 2005), or just as a strategic move to legally prevent rivals from utilizing it (Kitch, 1977; Mazzoleni & Nelson, 1998).

One of the few studies on the impact of knowledge value on firm-level outcomes is a study by Hall, Jaffe, and Trajtenberg (2005), where they examine how the value of created knowledge (measured as forward citations of patents) affects the stock market valuation of firms. A more recent study found that software patents of higher value are associated with higher market value for firms than less valuable patents (Hall & Macgarvie, 2010). Using the same measurement of knowledge value, Sampat and Ziedonis (2005) sought to predict the private economic value of knowledge using data on the licensing of new knowledge created by universities. While they found that knowledge value predicts the possibility of licensing a patent, they did not find a relationship between knowledge value and the revenue it brings when licensed. Bessen (2006) is another patents-related study where patents data is used to estimate the net present value of patents, given some patents-related characteristics such as patent renewal and firm size. Research on networks has also shown that the creation of valuable knowledge is associated with firms' growth, measured as increasing alliances with other firms (Demirkan et al., 2013; Rosenkopf & Padula, 2008).

The present study differs from prior research in that it seeks to assess the direct relationship between knowledge value and firm performance. While assessing the market value of firms is legitimate, it is still an outside evaluation of firms, which is beneficial in

cases of acquisition and purchases of firms' shares. In contrast, the current paper seeks to examine the annual performance of firms as it relates to the value of knowledge that they create. Additionally, the present paper studies how knowledge breadth moderates the aforementioned relationship, arguing that broader knowledge tends to be applicable in more industries; hence, is more profitable for firms. It should be noted that although the current paper uses patents as a proxy for knowledge created by firms, it does not look at the relationship from a legal point of view like many patents-related studies. Instead, it is a study that focuses on firm performance as an outcome of the value of the knowledge that firms create.

With those objectives, the present study contributes to the knowledge literature in two ways. First, it contributes to the debate on how knowledge creation influences firm performance, given that findings of prior studies have not been consistent. Second, while the majority of prior research has focused on the relationship between the amount of knowledge creation and firm performance, the current study focuses on the direct relationship between the value of created knowledge and firm performance. Thus, the paper emphasizes that it is not only the ability to create knowledge that matters; instead, the quality of created knowledge should also matter in generating revenue.

Third, the study also contributes to the knowledge literature by highlighting the importance of creating broad knowledge. Unlike the creation of narrow knowledge to build a core competence (Hamel & Prahalad, 2006), creating broad knowledge gives firms strategic flexibility to adapt to environmental changes (Leonard-Barton, 1995;

Tripsas & Gavetti 2000; Volberda, 1996). Previous studies have found a positive relationship between knowledge breadth and the development of radical innovation (Tripsas & Gavetti 2000; Zhou & Li, 2012). The present study argues that firms could generate higher revenue by creating knowledge that is not only valuable, but also broad rather than narrow.

The rest of the paper is structured as follows. First, I provide theoretical background on knowledge creation at the firm level. I then develop hypotheses on the relationship between knowledge value, knowledge breadth, and firm performance. Next, I discuss the methodology of the study, explaining the sample and the data collection process, along with the measures and the statistical technique used for analysis. I follow that with the results and the discussion sections before the conclusion of the paper.

## 4.2: Theoretical Background

### 4.2.1: Knowledge Creation and Firm Performance

Knowledge creation refers to the generation of new knowledge that did not exist before (Arrow, 1962; McFadyen & Cannella, 2004; Nonaka, 1994; Schumpeter, 1934). Knowledge resides within individuals (Polanyi, 1966), and the creation of new knowledge comes about through interactions among individuals (Fleming, 2001; Nonaka, 1994; Nelson & Winter, 1982; Polanyi, 1966; Rosenkopf & Nerkar, 2001; Schumpeter, 1934). Such interactions involve the exchange of diverse information that each individual possesses (McFadyen & Cannella, 2004; Nahapiet & Ghoshal, 1998). At the firm-level, knowledge-based theories assert that the role of firms is to combine, coordinate, and

integrate individual knowledge to form an overall firm knowledge (Grant, 1996; Nelson & Winter, 1982, Kogut & Zander, 1996). Nonaka, von Krogh, and Voepel (2006: 1179) define knowledge creation at the firm level as "the process of making available and amplifying knowledge created by individuals as well as crystallizing and connecting it with an organization's knowledge system." That being said, firms differ in their ability to create new knowledge, and the literature suggests that some critical resources are behind such differences.

First, because knowledge resides within individuals (Polanyi, 1966), it follows that the stock of knowledge that individuals within the firm possess is important (DeCarolis & Deeds, 1999; Smith et al., 2005). Knowledge stock is the overall knowledge that firms' employees have accumulated over time. Without a solid and diverse stock of individual knowledge, firms would not be able to find basic knowledge to combine or integrate in order to create new firm knowledge. Hence, knowledge firm is influenced, at least partially, by the stock of knowledge of their employees.

Second, the relationships that each employee has with his peers within the firm also represent an important resource for knowledge creation. In the network literature, such relationships are known as ego networks, defined as the set of alters to which each employee is directly tied (Nahapiet & Ghoshal, 1998). Networks are critical for knowledge creation because they represent a key element for knowledge exchange (Bouty, 2000; McFadyen et al., 2009; Nahapiet & Ghoshal, 1998). Specifically, they facilitate the process of knowledge flow among employees and provide a platform by

which employees can share their distinctive knowledge. Accordingly, firms in which employees are connected to each other and have effective relationships to exchange information tend to be more capable of creating knowledge.

Third, firm routines and processes are essential in enabling firms to create knowledge. They are integral not only in facilitating knowledge flow among individuals, but also in storing and organizing the collective knowledge of employees to form an organizational knowledge (Hargadon & Fanelli, 2002). When an employee leaves an organization, his tacit knowledge is typically lost. Yet, it is firm routines and processes that prohibit such a loss, because each individual's knowledge is embedded within those routines (Nelson & Winter, 1982). This is better explained by resource-based theory (Barney, 1991), which states that differences in firm performance are reflective of the resources that each firm possesses. The routines that each firm goes through in the knowledge creation process are firm-specific and, as a firm resource, are influential in firm-level knowledge creation.

The importance of creating knowledge for firms is well-established in the literature. Knowledge-based theories of the firm inform us that knowledge is the most critical resource that influences firm performance (Grant, 1996). The main premise of such theories is that through combination and integration of knowledge, and the coordination among involved units, firms are able to exploit knowledge as an input and produce profitable outputs (Grant, 1996; Inkpen, 2000; Kogut & Zander, 1996). Firms create new knowledge to have higher performance and to obtain a competitive advantage

(DeCarolis & Deeds, 1999). Given the amount of resources and the high costs that underlie the process of knowledge creation (DeCarolis & Deeds, 1999), it is vital to examine how creating new knowledge impacts their performance.

As mentioned above, knowledge is an asset from which firms could receive monetary returns (Grant, 1996; Teece, 1988). Essential to studying the impact of knowledge on firm performance is the term “appropriability,” which describes how likely the knowledge is valuable to its owner to receive rents equal to its value (Grant, 1996; Levitt & March, 1988; Teece, 1988). Knowledge appropriability depends on the type of knowledge. Two types of knowledge are commonly discussed in the literature: explicit knowledge, which is codified and easily translated; and tacit knowledge, which represents personal know-how that may be hard to confirm and transfer (Kogut & Zander, 1993; Nonaka & Takeuchi, 1995; Polanyi, 1975). Explicit knowledge is public and easy to imitate by others; therefore, it is likely to generate profits (Grant, 1996; Teece, 1988). On the other hand, tacit knowledge is usually firm-specific and hard to imitate, which could increase its appropriability (Teece, 1988).

Firms can use several strategies to generate financial revenues from the creation of new knowledge (Gambardella, Harhoff, & Verspagen, 2008; McGrath, Tsai, Venkataraman, & MacMillan, 1996). For example, as asserted by Schumpeter (1934), firms could commercialize new knowledge in the form of marketable products to reap profits. Firms could also out-license or sell their created knowledge to other firms (Moore, 2004; Sampat & Zeidonis, 2005). Alternatively, they could legally protect their



created knowledge through a patent (Kitch, 1977; Mazzoleni & Nelson, 1998), and subsequently build on it to create more related knowledge that could be profitable. Indeed, earlier research has found a positive relationship between firms' "intangible" capital, such as created knowledge, and firm market value (Griliches, 1981).

To summarize, firm create knowledge to obtain competitive advantage. However, while creating new knowledge could increase firm performance, it is critical to consider the value of created knowledge and how it could affect firm performance. In the next section, I discuss knowledge value and provide arguments on why it should influence firm performance.

#### 4.2.2: Knowledge Value

Knowledge value is a reflection of its impact, importance, and contribution to future knowledge (Albert et al, 1991; Nerkar & Paruchuri, 2005; Singh & Fleming, 2010; Trajtenberg, 1990). It is a representation about the scientific quality of the knowledge and how it is regarded in the scientific community. It is important to consider the values of created knowledge because they are not equal (Bozeman & Rogers, 2002; Singh & Fleming, 2010; Trajtenberg, 1990). Some knowledge tends to be of higher value than others, either because they are frequently recombined to create more knowledge (Fleming, 2001; Nonaka, 1994), or because they tend to be used more repeatedly than others (Bozeman & Rogers, 2002). On the other hand, some created knowledge is of less value. That is, it does not contribute to the creation of new knowledge, and is less likely to be commercialized. Such knowledge is deemed "worthless" (Moore, 2004).

As mentioned earlier, knowledge of high value is usually the foundation of future knowledge (Nerkar & Paruchuri, 2005). To illustrate, new knowledge tends to be created via the recombination of existing ones (Fleming, 2001; McFadyen & Cannella, 2004; Nonaka, 1994; Singh & Fleming, 2010), and knowledge that is recombined more than others is thought to be more impactful. Another indication of knowledge value stems from its impact on multiple fields. Such knowledge could have implications in different scientific areas and its applications could influence several industries. For example, Newton's laws of motion have a great impact in physics as well as math, and have been heavily credited as the basis for several scientific phenomena, which speaks about the value of such knowledge.

Measuring the value of knowledge presents multiple challenges, including the dramatic shifts in knowledge value over time and the difficulty to examine the economic value of knowledge (Bozeman & Rogers, 2002). Several attempts have been made to come up with an adequate measure of knowledge value. For example, Bozeman and Rogers (2002) developed a social-based framework to measure the scientific value of knowledge. The model focuses on knowledge's capacity to produce new one and the impact it has in enhancing the knowledge of its creators. Others relied on patents as a proxy for knowledge and used data on patents renewal to measure knowledge value, arguing that inventors are likely to renew valuable patents (Bessen, 2006; Moore, 2004). That being said, patents citations have been adopted as the common measure of knowledge value in the literature (e.g. Hall et al, 2005; McFadyen et al, 2009; Nerkar & Paruchuri, 2005; Singh & Fleming, 2010; Trajtenberg, 1990).

As illustrated earlier, firms create knowledge and expect to have positive financial returns. However, given that some created knowledge has higher value than others (Trajtenberg, 1990), I suggest that more valuable knowledge is expected to generate higher revenues than those with lesser value. Prior research has shown that knowledge value does, indeed, contribute to the financial success of firms. For instance, Hall et al (2005) found that firms that possess knowledge of high value have higher market value than those with less valuable knowledge. Likewise, Bessen (2006), using patents renewal data, found that more important knowledge has higher net present value. Along the same line, other factors being equal, I expect firms that create more valuable knowledge to experience more financial success than those creating knowledge of lesser value.

First, knowledge is an appropriable asset that firms create as a foundation for a potential invention (Teece, 1988). Consequently, inventions are combined in novel ways to come up with a commercializable product (Schumpeter, 1934). Knowledge-based theory of the firm (Grant, 1996) informs us that the success of a new product is, in part, a reflection of the characteristics of its underlying knowledge and the firms' abilities to manage and implement it. Due to its unique and impactful characteristics, knowledge of high value is likely to result in a product that is advanced technologically and more marketable. Also, the product is expected to be different and of higher quality (Porter, 1980), and, consequently, customers are expected to rate it favorably.

Second, knowledge creation is a path-dependent process (Dosi, 1982). That is, the creation of new knowledge is a byproduct of the current stock of knowledge. Therefore,

although not all knowledge is practically usable or commercializable, a highly valuable knowledge could be the foundation of other knowledge that firms could appropriate in the future. Creating such knowledge is significant for firms that strive to build a portfolio of knowledge as a base for component-based products (Gittelman, 2008) or just to hold a good position in the “portfolio race” (Hall & Ziedonis, 2001). For instance, Google did not commercialize all the patents it acquired from Motorola. However, the possessions of such patents allowed Google to add significant inventions to its portfolio that the company could build on for future products. Thus, even uncommercializable knowledge is eventually valuable for firms and they expect to profit from.

Third, firms could sell or out-license valuable knowledge to other firms. Unlike selling, licensing might be pursued by knowledge creators to grant permission for others to utilize their patented knowledge without giving up ownership. When sold or out-licensed, valuable knowledge should generate higher fees than less valuable ones. Buyers or licensees of such knowledge recognize the potential of such knowledge, whether due to its immediate exploitability or its importance in creating future profitable knowledge (Gambardella et al, 2008). For instance, not only did Google purchase patented knowledge from Motorola, but it also signed a license agreement with Samsung to take advantage of Samsung’s portfolio of inventions. Obviously, Google took on such transactions predicting that the value of such knowledge should contribute to its financial success eventually.

For the aforementioned reasons, whether through commercializing, recombining

with other knowledge, or by licensing and selling, I suggest that firms that create knowledge of high value should generate more revenues than those creating less valuable knowledge.

*Hypothesis 1: There is a positive relationship between the value of created knowledge and firm performance.*

#### 4.2.3: Knowledge Breadth

Different dimensions of knowledge base have been studied in the literature, such as its size (e.g. Ahuja & Katila, 2001; Fleming, 2001), its relatedness to other knowledge (e.g. Lane & Lubatkin, 1998), and its decomposability (e.g. Yayavaram & Ahuja, 2008). In the current study, the focus is on knowledge breadth, which is one of the most important and commonly studied dimensions of knowledge base (Prencipe, 2000; Zhang, Baden-Fuller, & Mangematin, 2007; Zhang, 2016; Leiponen & Helfat, 2010).

The level of analysis in our study is at the knowledge level. Thus, I define knowledge breadth as the extent to which the knowledge created by firms contain distinct and multiple domains (Bierly & Chakrabarti, 1996; Zhou & Li, 2012). It represents the horizontal domains of knowledge (De Luca & Atuahene-Gima, 2007) and the different technological areas where the knowledge is applicable (Leiponen & Helfat, 2010; Zhang, 2016).

A valuable knowledge with distinct and multiple domains is advantageous for firms for a number of reasons. First, unlike narrow knowledge that has limited usability,

broad knowledge is flexible and could be combined with different knowledge (Bierly & Chakrabarti, 1996). Because the creation of new knowledge comes likely from the combination of existing ones (Fleming, 2001; Nonaka, 1994), broad knowledge that belongs to or is applicable in different areas tends to have more chance of being recombined. Prior research has emphasized that broader knowledge provides firm the opportunity to couple distinct knowledge, which could lead to the discovery of new ones (Yayavaram & Ahuja, 2008). Therefore, one of the important implications of having broad knowledge is the high likelihood of creating new ones.

Second, broad knowledge enables firms to better understand external information and the technological changes in the environment (Chesbrough, 2003). This is better explained through the concept of “absorptive capacity” (Cohen & Levinthal, 1990; Zahra & George, 2002), which states that firms with higher levels of absorptive capacity are more likely to recognize the value of new information, assimilate it, and apply it to commercial ends. Being limited to narrow and more specialized knowledge makes firms vulnerable to new technologies and environmental change, which leads to rigidity and the failure of firms (Tripsas & Gavetti 2000; Tripsas, 1997; Tushman & Anderson, 1986). Thus, creating broad knowledge allows firms to adapt to environmental change and to avoid potential failure that results from the inability to recognize and understand new technologies.

Third, broad knowledge increases firms’ opportunities to develop radical innovations. To explain, prior studies suggest that radical innovation usually stems from

the combination of broad and distinct knowledge (Taylor & Greve, 2006; Tripsas & Gavetti 2000; Zhou & Li, 2012), while incremental knowledge is likely the result of deep and specialized knowledge (Zhou & Li, 2012). As put by Taylor and Greve (2006), the application of diverse knowledge tends to result in more novel innovations, while the deep application of existing knowledge leads to less novel innovations. Another benefit of broad knowledge that is related to the development of new products is that products built from the exploitation of broad and diverse knowledge could serve distinct industries; hence, increasing firms' chances of generating revenues from multiple sources (Teece, 1988).

On the other hand, while they tend to have a “core competence” (Hamel & Prahalad, 2006) and an in-depth knowledge on specific areas, firms that creates narrow knowledge are often limited in their exploitations options (Tripsas & Gavetti 2000). Narrow knowledge is usually specific and utilizable only in the intended field. Indeed, recent research shows that firms with narrow knowledge are associated with incremental innovation, focusing on their current customers, and unable to explore and implement new ideas, unless they have access to external knowledge (Zhou & Li, 2012).

Additionally, previous studies posit that deep and less diverse knowledge limits firms from recognizing external knowledge and, eventually, leads to failure (Tripsas & Gavetti 2000; Tripsas, 1997; Tushman & Anderson, 1986). While it allows for developing incremental innovations, less broad knowledge may limit firms from the exploration and the development of novel innovations (Tripsas & Gavetti 2000; Zhou &

Li, 2012).

Based on the aforementioned arguments, I suggest that knowledge breadth is a variable that positively moderates the relationship between knowledge value and firm performance. I posit that, while knowledge of high value is essential for firms, those creating valuable and broader knowledge are more likely to benefit from their valuable knowledge than those creating valuable but narrower knowledge. Specifically, I suggest that the former are more likely to convert their knowledge into innovative products that could be utilizable in several industries. From an evolutionary perspective, the broad knowledge they create is expected to be more beneficial in creating new and more novel knowledge in the future. Simply put, I expect the value of created knowledge to increase proportionally with knowledge breadth. Hence, I expect firms with valuable and broad knowledge to be more successful financially than those with valuable but less broad knowledge.

*Hypothesis 2: Knowledge breadth will moderate the relationship between the value of created knowledge and firms' financial performance in such a way that firms with valuable and more broad knowledge will generate more revenue than those with valuable but less broad knowledge.*

## 4.3: Methods

### 4.3.1: Sample

I elected to choose the U.S biotechnology industry as a research setting. Biotechnology is an industry that is widely used in the literature of knowledge creation



and innovation (e.g. DeCarolis & Deeds, 1999; Gittelman & Kogut, 2003; Phene, Fladmoe-Lindquist, & Marsh, 2006; Schilling & Phelps, 2007; Zucker, Darby, & Armstrong, 2002) and is an industry where creating new knowledge is very common (Sorensen & Stuart, 2000).

A list of biotechnological firms was identified from COMPUSTAT using the SIC: 2836. I matched those companies with the NBER database (Hall, Jaffe, & Trajtenberg, 2001) to identify all patents granted to those firms in the period 1976-2006. For patents-related data, the USPTO website was used in cases where values were missing and for confirmation purposes. Likewise, Mergent Online was used to check for financial data that were not available in COMPUSTAT.

For consistency, reliability, and comparability (Ahuja, 2000), I concentrated on patents granted at the United States Patents and Trademark Office (USPTO). The USPTO database provides rich and longitudinal information, including data on inventors who created the knowledge, patents citations, the date patent was granted, and classes under which the patent falls. Such information allows for measuring several variables related to the study. Also, it is highly used in research where patents are used to measure knowledge creation, as in the current paper (e.g. Ahuja, 2000; Funk, 2014; Schilling & Phelps, 2007; Singh & Fleming, 2010).

Consistent with previous studies (e.g. Fleming et al, 2007; McFadyen et al, 2009), I used a three-years moving window to predict the financial performance of each firm in each focal year. Specifically, I averaged the values on each variable from the previous

three years for my measures of independent and control variables to predict firm performance. It should be noted that firms' data were not available for every firm in every year. Thus, I collected data on each firm starting from the first year where data were available. The first three years of data for each firm were used only for measurement of independent and control variables, and the first prediction performance started in the fourth year for each respective firm. After deleting entries with missing values and some outliers, I had an unbalanced panel data of 58 firms and 480 firm-year observations.

#### 4.3.2: Dependent Variable

*4.3.2.1: Firm performance.* To measure firm performance, I used return on assets, an accounting measure of performance that is commonly used in the literature (e.g. McDonald, Khanna, & Westphal, 2008).

#### 4.3.3: Independent Variable:

*4.3.3.1: Knowledge value.* Following previous studies, knowledge value is measured based on the forward citations a patent receives (e.g. Capaldo et al., forthcoming; Fleming, 2001; Hall et al, 2005; Phene et al, 2006; Trajtenberg, 1990). Forward citations reflect the relative importance of the underlying knowledge of a patent (Trajtenberg, 1990). Due to the fact that some classes of patents receive greater rates of patenting and technological advancement than others (Griliches, 1981; 1990; Trajtenberg, 1990), I standardize forward citations with class and year to control for this issue. Specifically, I calculate an overall average citations rate per class for each firm/year. This will provide

an indicator of each patent's value relative to all patents in the same class.

*4.3.3.2: Knowledge breadth.* I measured knowledge breadth as the number of classes under which the patent is classified. This is a common measure of knowledge breadth in knowledge-related literature (e.g. Fleming, 2001; McNamee, 2013; Nerkar & Paruchuri, 2005; Toh, 2014). The USPTO divides patents into over 400 technological classes, and each patent is classified under the class where that patent is usable. For example, inventions related to pharmaceutical applications belong to the category of drugs and bio-affecting compositions (Class 514), and inventions related to microbiological applications are classified under the category of molecular biology and microbiology (Class 435). Such classification reflects the scope of usability of a patent and research shows that it affects the impact of the focal patent (Lanjouw & Schankerman, 2001). Because knowledge breadth is a moderating variable in the current study, the interaction of knowledge value and knowledge breadth was calculated as the multiplication of the mean-center of both variables.

#### 4.3.4: Control Variables:

Several control variables were included in the model. Firms differ in their ability to integrate knowledge and coordinate between the different units within the firm in order to create new knowledge (Grant, 1996). Thus, to control for firm differences, I included number of employees as a measure of *firm size*. I also included *R&D intensity* (Cohen & Levinthal, 1990) as a control variable, which is common in studies related to knowledge creation and innovation (e.g. Lahiri & Narayanan, 2013), and because it has been

suggested as a critical factor to firm performance (DeCarolis & Deeds, 1999). It was measured as firms' average R&D expenditure divided by its average total asset for the three years preceding the year firm performance is predicted. Other control variables were initially included in the analysis (e.g. number of patents, patent claims, time to grant, lagged revenues, sales), but were removed later because they showed high correlations with other variables.

#### 4.3.5: Analysis

Due to the nature of the data as a time-series cross-sectional one, pooling repeated observations on the same firms is likely to violate the assumption of independence (Shipilov, 2006). Also, efficient and unbiased regression estimation of such time series cross-sectional might need corrections because error terms for cross-sectional observations might be heteroskedastic. Indeed, employing the Cameron & Trivedi's decomposition of IM-test in STATA reveals that there is a heteroskedasticity problem. There are also the problems of cross-sectional correlations and within-panels autocorrelation (Nair & Kotha, 2001). For the aforementioned reasons, ordinary Least squares estimates are inefficient. Hence, I use generalized least squares (GLS) estimation as an analytical technique in the current study. Random-effects models will be used to evaluate effects of the independent variables based on both within- and between-organization variances (Greene, 1993).

#### 4.4: Results

Table 1 shows descriptive statistics and correlations among the variables. Multicollinearity does not seem to be an issue, given that the VIF of each variable is well below 10 (Belsey & Welch, 1980). Regression models and tests of my hypotheses are presented in table 2. Model 1 includes the control variables, while the independent variables are introduced in model 2, and the moderating variable in model 3.

Hypothesis 1 predicted that there is a positive relationship between knowledge value and firm performance. Model 2 shows that the relationship is significant and in the predicted direction ( $\beta = 0.021$ ,  $p < 0.05$ ). Thus, it provides statistical evidence that the more valuable knowledge a firm creates, the higher its performance. Hypothesis 2 predicted that the relationship between knowledge value and firm performance is positively moderated by knowledge breadth. Centered values of knowledge value and knowledge breadth were used for the interaction term to account for any possible issue of multicollinearity. Model 3 shows statistical support for the moderating role of knowledge breadth ( $\beta = 0.026$ ,  $p < 0.01$ ), suggesting that the impact of knowledge value on firm performance is likely to increase as the breadth of the knowledge increases.

Table 4-1: Descriptive Statistics

|                                     | Mean | SD    | 1     | 2     | 3     | 4     | 5    | 6    |
|-------------------------------------|------|-------|-------|-------|-------|-------|------|------|
| Firm Performance                    | 0.37 | 0.39  | 1.00  |       |       |       |      |      |
| Knowledge Breadth                   | 0.92 | 1.14  | 0.05  | 1.00  |       |       |      |      |
| Firm Size                           | 3.27 | 11.62 | 0.36  | -0.14 | 1.00  |       |      |      |
| R&D intensity                       | 0.33 | 0.30  | -0.18 | -0.04 | -0.26 | 1.00  |      |      |
| Knowledge Value                     | 0.94 | 1.86  | 0.10  | 0.45  | -0.07 | -0.04 | 1.00 |      |
| Knowledge Value x Knowledge Breadth | 0.95 | 2.53  | 0.17  | 0.37  | -0.03 | -0.01 | 0.60 | 1.00 |

Table 4-2: GLS models predicting firm performance \*

| <i>Variable</i>           | Model 1           | Model 2           | Model 3           |
|---------------------------|-------------------|-------------------|-------------------|
| Knowledge Breadth         | 0.03*<br>(0.01)   | 0.02<br>(0.02)    | 0.01<br>(0.02)    |
| Firm Size                 | 0.01**<br>(0.001) | 0.01**<br>(0.001) | 0.01**<br>(0.001) |
| R&D Intensity             | -0.12*<br>(0.06)  | -0.12*<br>(0.06)  | -0.12*<br>(0.06)  |
| Knowledge Value           |                   | 0.02*<br>(0.01)   | 0.01<br>(0.001)   |
| Kno. Value x Kno. Breadth |                   |                   | 0.03**<br>(0.01)  |
| Wald X <sup>2</sup>       | 81.86             | 87.10             | 99.50             |
| Log-likelihood            | -193.032          | -190.80           | -185.61           |

\* All models are derived from maximum-likelihood GLS with standard errors (reported in parentheses). \* p <.05 , \*\* p < .01

#### 4.4.1: Robustness Analysis

An additional analysis was conducted to make sure the results of my models are robust. In a set of models not reported in the dissertation, I controlled for more patents- and firms-related variables. Specifically, I controlled for the number patents granted for each firm per year, the average number of claims, the average time it took to grant patents, total sales, and the average revenue of firms for the precedent three years. Those variables were highly correlated to other variables in the reported models and didn't contribute significantly to the model when initially included. The results didn't change

when those control variables were added to the model, indicating that the findings of the current paper are robust.

#### 4.5: Discussion

The present study sought to examine the impact of the knowledge value on firm performance, and to evaluate the moderating role of knowledge breadth on that relationship. The findings supported the hypothesis that the value of the knowledge that firms create is positively related to firm performance. They also supported the hypothesis that valuable knowledge that is broad has more influence on firm performance than valuable but less broad knowledge.

I proposed that knowledge value has a positive relationship with firm performance. Knowledge of high value is thought of as important and more impactful (Albert et al., 1991; Fleming, 2001; Trajtenberg, 1990; Hall et al, 2005). Research asserts that important knowledge is used more frequently than less important ones (Bozeman & Roger, 2002). Such knowledge are likely to be exploited and converted into commercialized products (Schumpeter, 1934; Teece, 1988) or could be the foundation of future knowledge (Nerkar & Paruchuri, 2005; Podolny & Stuart, 1995). The findings in the current paper provide evidence that firms that create knowledge of high value are more likely to have higher performance than those that create knowledge of less value.

I also predicted that knowledge breadth would positively moderate the relationship between knowledge value and firm performance. Broad knowledge is characterized by high flexibility and the ability to be recombined with other distinct



knowledge (Bierly & Chakrabarti, 1996). The ability to be recombined with other knowledge leads to the creation of new ones (Fleming, 2001; Nonaka, 1994). Also, firms that create broad knowledge have an advantage in recognizing and understanding external knowledge (Chesbrough, 2003), which eventually increases their absorptive capacity (Cohen & Levinthal, 1990; Zahra & George, 2002). Research has also found a positive relationship between creating broad knowledge and the ability to develop radical innovations (Taylor & Greve, 2006; Tripsas & Gavetti 2000; Zhou & Li, 2012). The findings provide evidence that firms that create scientifically valuable and broad knowledge achieve higher financial performance than those that create valuable but less broad knowledge. Put differently, creating knowledge that is utilizable in creating other new knowledge, used and applied frequently and in multiple areas is positively associated with firm performance.

The paper contributes to the literature in multiple ways. First, it contributes to a stream of research that emphasizes the importance of creating knowledge of high scientific value to firm-level outcomes. Previous studies assert that having a portfolio of valuable knowledge is a great asset that increases firms' market value (Hall et al, 2005; Hall & Macgarvie, 2010), while others have shown a positive relationship between creating valuable knowledge and firm growth (Demirkan et al., 2013; Rosenkopf & Padula, 2008). The current paper is one of few studies known to the author that provide evidence that the value of created knowledge has a direct effect on firm financial performance.

Second, the paper contributes to the knowledge literature by emphasizing how knowledge breadth significantly influences the impact of knowledge value on firm performance. Prior studies provided evidence that firms with broad knowledge understand external knowledge more than those with less broad knowledge (Chesbrough, 2003). Others have shown that broad knowledge is beneficial in developing radical innovations (Taylor & Greve, 2006; Tripsas & Gavetti 2000; Zhou & Li, 2012). On the other hand, the current paper posits that valuable knowledge could have greater impact on firm performance if the focal knowledge is broad. It highlights the importance of creating knowledge that could be combined with other distinct knowledge, and that could be exploited and developed into products usable in different industries.

#### 4.5.1: Limitations and Future Research

While the paper provides contributions to the knowledge literature, some limitations are worth noting. First, although the paper controlled for various variables that could contribute to firm performance, other factors that I did not control for might have influenced firm performance. For example, while firms could develop valuable knowledge into products, the success of such products could be partially influenced by advertising and other marketing activities. Unfortunately, data on advertising expenditure were mostly missing from COMPUSTAT for the majority of firms; hence, I could not include it as a control variable. However, I believe that the factors included in the analysis and particularly, in the additional analyses, are enough to control for internal factors that could affect firm performance.

Second, environmental factors, which the current paper does not account for, could also impact firm performance. For instance, governmental regulations or certain economic situations out of firms' control could have contributed to firm performance, regardless of how valuable the knowledge each firm created. However, the current study follows the knowledge-based theory (Grant, 1996), which focuses on firms' internal resources as the most important factor that shapes firm performance. Additionally, I believe that focusing on one specific industry and having a time series data that covers 58 firms working in a long period should minimize the effect of such external factors.

Nevertheless, the paper builds on previous studies on knowledge creation and how they contribute to firm success, and opens the door for future research in the area. For example, scholars interested in knowledge-related research could investigate the roles of other moderating variables that could influence the relationship between knowledge value and firm performance. While the current paper assesses the influence of knowledge breadth, others could provide counter arguments and examine how knowledge depth could affect the impact of knowledge value on firm performance. Previous studies suggest that having an experience in one domain enables firms to properly implement innovative ideas and develop them into successful products more so than possessing broad knowledge (Tripsas & Gavetti 2000; & Zahra & George, 2002). It would be interesting to find out how the role of knowledge depth would differ from that of knowledge breadth.

Other areas for future research include developing an overall framework on what

strategies firms could implement to take advantage of the value of their created knowledge. Some studies have suggested some tactics that could help in generating rents (e.g. Gambardella et al, 2008), such as exploiting valuable knowledge to create innovative products (Schumpeter, 1934), protecting valuable knowledge by applying for a patent to secure exclusive rights to it or out-licensing it to other firms for a fee (Mazzoleni & Nelson, 1998). That being said, it would be more compelling to consolidate all tactics and activities into an overarching framework that firms could adopt to convert their valuable knowledge into profitable assets.

#### 4.6: Conclusion

The study provides new insights into the relationship between knowledge creation and firm performance. I also believe that it has implications for managers. Due to the huge volumes of funds required for firms to create new knowledge, the study emphasizes that, while creating new knowledge is helpful, firms should focus more on creating knowledge of high value. In other words, the study provides evidence that the quality of knowledge should be significantly considered when creating new knowledge. This finding suggests that when allocating resources towards R&D, managers should prioritize the creation of highly valuable knowledge, even if it occasionally results in creating fewer number of patentable knowledge. The paper also suggests that creating valuable knowledge that is broad and flexible should be an important objective for managers as it provides more opportunities to generate future rents. Such rents could be the results of developing radical innovations, selling a patented-knowledge of high value to other

firms, or just to have a strong foundation of valuable knowledge that the focal firm could recombine with other knowledge to create new ones in the future.

## Chapter 5:

### Discussion and Conclusion

This dissertation set out to explore the interplay among networks, knowledge value, and performance. Specifically, it sought to examine changes in network structure, the influence of certain network characteristics on knowledge value, the impact of knowledge value on firm performance. Through three essays, the dissertation provided answers to three main questions. First, in a network of knowledge workers, *how do network resources and knowledge utilization predict changes in network structure?* Second, in a network of knowledge workers, *how do network size and network diversity influence the value of knowledge created by networks of knowledge workers?* Third, *does the value of the knowledge created by firm's impact their performance?*

Three empirical studies were conducted in order to investigate the issues raised by the three aforementioned questions. Chapter II used the NBA as a research setting and focused on the dynamics of networks. Particularly, it sought to examine factors that contribute to changes in network structure. Chapter III tackled the second question of the study. Using data on patents granted to Saudi inventors by the USPTO, the study assessed the impact of network size and network diversity on knowledge value. Chapter IV was dedicated to a study that went beyond the network-level of analysis and focused on the firm level. Using data on patents granted to biotechnological firms in the U.S., the study examined whether knowledge value is positively associated with firm performance.

In the following section I provide a summary of the findings of the three empirical studies, discuss the overall contribution of the dissertation, including some directions for future research. The section concludes with some managerial insights that the dissertation provides.

### 5.1: Summary of Findings

The purpose of chapter II was to conduct a study at the network-level to empirically examine network-related factors that predict network change. The NBA was used as a research setting due its suitability to studies related to networks and knowledge, given the treatment of basketball players as knowledge workers in the literature and the interdependency among basketball players (Berman et al., 2002).

The findings revealed that network resources have an impact in shaping the structure of future networks. Two measures of network resources were used in the study: available cash and draft picks. When available cash was used as a measure of network resources, the findings provided evidence that the more resources a network has, the more likely it is to experience changes in its structure. However, when draft picks were used as a proxy for network resources, the results were not significant. Overall, the study suggests, at least partially, that network resources are an important factor that contributes to changes in network structure.

In addition to network resources, knowledge utilization was used as a factor that influence network change. Using the average level of knowledge utilization among the five players that represent the network, the study provides significant evidence that knowledge utilization, indeed, is negatively associated with network change. That is,

when knowledge workers in a network are utilizing the knowledge they possess effectively, the chances that a knowledge worker would leave the network diminishes.

Chapter III used data from the USPTO on knowledge created by knowledge workers in Saudi Arabia to investigate whether knowledge size and network diversity affect the value of the created knowledge. The decision to use data on knowledge created by Saudi inventors was motivated by the need to test how having knowledge workers from developed countries in the network would impact the value of created knowledge. Since the majority of network and knowledge studies are conducted using samples from developed countries, it was also an opportunity to address the generalizability of findings employing data from a developing country, knowing that characteristics of knowledge and knowledge workers in such countries are more likely to be different than those in developed countries.

The findings showed that network size positively affect the value of knowledge created by a network of knowledge workers. The findings suggest that, generally, having more knowledge workers in the network should bring more expertise to the network and, subsequently, should lead to creating more valuable knowledge. Prior studies found that increasing network size is usually associated with high cost of coordination and maintenance that comes with relationships (e.g. Burt, 1992; Gulati & Singh, 1998). That being said, the focus in chapter III was on the scientific value of the created knowledge, regardless of how much it did cost.

The findings also revealed that diverse networks are more likely to create knowledge of high value than those with less diversity. Having network members with



different backgrounds and areas of expertise provide an opportunity to evaluate ideas and solve problems based on different values and from distinct point of views, which should lead to more rigorous process and more novel ideas (Fleming, 2001). The arguments is even stronger for knowledge workers from developing countries, given that they usually lack access to new knowledge created commonly by developed countries (Prahalad, 2005). Thus, including knowledge workers from developed countries in the network brings advanced knowledge to the network that otherwise would not be available to the network.

Finally, chapter IV used data on biotechnological firms in the U.S to examine if the value of the knowledge they create impact their performance. Data on patents from the NBER were matched with firm-level data from the COMPUSTAT in the study. The biotechnological industry is one where creating new knowledge is very common (Sorensen & Stuart, 2000) and is frequently used in the literature (e.g. DeCarolis & Deeds, 1999; Gittelman & Kogut, 2003; Phene et al., 2006; Schilling & Phelps, 2007; Zucker et al., 2002).

The findings supported the hypotheses of the study, indicating that firms that create knowledge of high value tend to achieve better performance than those creating less valuable knowledge. Thus, the study provides evidence that the quality of the knowledge firms create matter more than the quantity. To explain, prior studies asserts that knowledge of high value is thought of as important, more impactful, and is used more frequently than less important ones (Bozeman & Roger, 2002; Fleming, 2001;

Trajtenberg, 1990; Hall et al, 2005). Such knowledge are likely to be exploited and converted into commercialized products (Schumpeter, 1934; Teece, 1988) or could be the foundation of future knowledge (Nerkar & Paruchuri, 2005; Podolny & Stuart, 1995). Therefore, creating such knowledge should contribute positively to firm performance.

## 5.2: Theoretical contributions

The three studies comprising this dissertation collectively make the following contribution. First, given the importance of understanding the dynamics of networks (Ahuja et al., 2012), I examine how network resources and knowledge utilization affects the structure of networks. I complement recent research on network dynamics (e.g. Cannella & McFadyen, forthcoming; Sytch & Tatarynowicz, 2014) and introduce factors that contribute to structural changes of networks. I find that resources available within the focal networks are positively associated with changes in its structure, while the extent to which actors are utilizing their knowledge as part of a network does, evidently, affect the structure of their network.

Second, the dissertation contributes to a stream of research that focuses on the value of knowledge created by knowledge workers, acknowledging that knowledge does not have equal value (Albert et al, 1991; Nerkar & Paruchuri, 2005; Singh & Fleming, 2010; Trajtenberg, 1990). Specifically, I investigate how the value of knowledge created by knowledge workers is affected by the characteristics of the focal network. The dissertation supports recent findings by Singh and Fleming (2010) that network size has a positive impact on knowledge value. However, contributing to the international business

literature, I use a sample of a developing country to test the generalizability of the proposition that network size affects knowledge value. Additionally, while the benefits of having a diverse network of knowledge workers is well established (e.g. Ahuja, 2000; Burt, 1992; Granovetter, 1973; Reagans & Zuckerman, 2001; Smith et al, 2005), the dissertation complements those studies by providing evidence that diverse networks are also recommended to create valuable knowledge.

Third, the dissertation examines the impact of knowledge value on firm performance. Departing from prior studies on the relationship between knowledge value and other firm-level outcomes such as market value (e.g. Hall et al., 2005; Hall & Macgarvie, 2010), I provide evidence that the value of knowledge that firms create affect their financial performance. I also highlight the importance of creating broad knowledge to extend the appropriability of the knowledge that firms create.

Overall, the dissertation contributes to the network-knowledge literature by focusing on the dynamics of network of knowledge workers and how the network characteristics affect the value of the knowledge they create, and how that value eventually impacts firm performance. Future research is still needed to further advance our understanding of the complex and interesting relationship between networks and knowledge value.

### 5.3: Managerial implications

The dissertation provides some salient managerial implications. First, it illustrates one aspect of network dynamics, highlighting that networks of knowledge workers evolve and change over time. Network resources and knowledge workers' ability to utilize their knowledge within the network are evidently influential in shaping the future structure of networks. Thus, the lesson for managers in charge of networks of knowledge workers here is that it is vital for them to possess resources and control them in a way that enables them to change the structure of their network as they deem necessary.

Additionally, the dissertation informs managers that providing environments in which knowledge workers could utilize their knowledge is of high priority. Such environments include pairing knowledge workers with partners they can collaborate with smoothly and effectively, and securing resources that allow them to perform the tasks required of them. Otherwise, managers should expect the departure of some workers due and, consequently, a change in their overall structure.

Second, the dissertation provides evidence that some characteristics of networks are beneficial in enabling the creation of valuable knowledge. Specifically, it suggests that forming a large network of knowledge workers increases the chance of creating knowledge of high value. Additionally, the dissertation illustrates that forming a diverse network with different and unique backgrounds is also associated with creating valuable knowledge. Importantly, for managers in charge of networks of knowledge workers in a developing country, the dissertation emphasizes the importance of having more members in the network, and specifically members from developed countries to have an access the

advanced knowledge that is usually created in developed countries. Such a strategy would enable networks to combine the knowledge of their own with that from knowledge workers from developed countries in order to create new valuable knowledge.

Finally, an important insight from the dissertation is that the value of created knowledge does matter. That is, the value of the knowledge a firm creates is positively associated with its performance. Therefore, firms should strive to not only create huge amount of knowledge; instead, focusing on the quality of knowledge should be the priority. Resource allocations for R&D and research projects should be directed towards the creation of valuable knowledge that firms could exploit and convert into successful products. Alternatively, valuable knowledge could be combined with other knowledge to create future novel knowledge. At the very least, firms could out-license or sell the rights to their valuable knowledge for a hefty fee. Purchasing patents that are built on a valuable knowledge is a common strategy in several industries, especially those where knowledge is essential for firms' growth and success (e.g. computer manufacturing or biotechnology).

In summary, the dissertation informs managers of networks of knowledge workers about the dynamism of networks and how to better control the structure of their networks. It also highlights ways by which networks are able to create valuable knowledge, and how such knowledge could be lead to higher firm performance.

#### 5.4: Conclusion

The literature that connects networks with knowledge is rich and continually growing. This dissertation is an attempt to contribute to the literature and complement prior studies that helped building such a literature. While I believe the dissertation provides some theoretical and managerial insights, it has its own limitations. Future research is still much needed to further advance our knowledge of network dynamics and their influence in the creation of valuable knowledge.

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