# Divide to connect: Reorganization through R&D unit spinout as linking context of intra-corporate networks

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**Abstract**
The paper examines the formation of clique-spanning ties in intra-corporate co-invention networks, by focusing on the impact of R&D unit spinouts. Using data on thirty-one spinouts in eight large U.S. information and communication technology corporations, we show that the reorganization of R&D units through corporate spinouts is associated with an increase in the extent to which inventors employed in the unit collaborate with inventors located in other cliques within the corporate co-invention network. Interestingly, the spinout effect spills over to all members of the clique of spun-out inventors, also including those who remain with the parent firm. The interpretation of these empirical findings, grounded on existing theories and on the views of inventors and executives involved in the reorganization events, suggests that corporate spinouts generate a shock in intra-corporate research collaboration dynamics, which loosens clique lock-in effects and contributes to reset cliques' boundaries in the intra-corporate research network.

**Keywords:** Corporate spinout; Intra-corporate collaboration network; Reorganization; Clique-spanning tie; Patents.

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## 1. Introduction

A key insight of the recent literature on the economics and management of innovation is that creativity does not take place in isolation, but is the outcome of a thick web of knowledge exchanges and collaborations both within and across organizations. Prior studies have shown that research collaboration networks tend to evolve over time towards a small world architecture (Watts, 1999). This specific network structure has two peculiar features: (1) locally cohesive cliques (also called communities or clusters), comprising groups of actors (e.g., R&D employees) densely connected to one another but sparsely connected to others, and (2) clique-spanning ties, or links that connect actors located in distinct and otherwise disconnected cliques (Ahuja et al., 2012).

For firms, a small world co-invention network represents a nearly ideal structure for fostering knowledge production and recombination, for two reasons. First, the density of collaboration within cliques induces high levels of structural cohesion (Granovetter, 1973; Moody and White, 2003), which conveys a normative order (Podolny and Baron, 1997), common values, cultures of action, social norms, procedures (Rowley et al., 2000), and the development of trust (Gulati, 1995). By easing knowledge sharing and fostering the transmission of fine-grained information among people embedded within cliques (Burt, 2001), these factors spur localized learning and independent exploitation of specialized technologies (Reagans and McEvily, 2003). Second, clique-spanning ties are instrumental for diffusing knowledge and information beyond the cliques' boundaries, thus facilitating the exploration and recombination of ideas and knowledge (Cowan and Jonard, 2004; Lazer and Friedman, 2007).

Despite broad consensus on the importance of small-world architectures for innovation, we still know relatively little about the mechanisms that lead to the formation of such structures over time. First, substantial effort has been devoted to understanding the cliquish nature of research networks (Rivera et al., 2010), yet much less is known about the factors that affect the formation of clique-spanning ties. Second, prior research has mostly examined clique-spanning ties in inter-firm (e.g., Powell et al., 2005; Rosenkopf and Padula, 2008) and in regional networks (e.g., Fleming et al., 2007; Ter Wal, 2013), and we still know little about whether these same mechanisms may have explanatory value in intra-firm networks, such as contexts where individuals are subject to bureaucratic and hierarchical constraints, which drive their collaboration efforts. Understanding how organizations may connect intra-firm cliques of R&D employees thus looks critically important in explaining the process of knowledge recombination at the intra-firm level (Katila and Ahuja, 2002; Tsai, 2000).

With this study, we aim to shed light on this issue by examining the process of intra-corporate clique-spanning tie formation in the context of structural reorganizations of corporate research and development (R&D) units. Extant literature has emphasized the importance of structural reorganizations for enabling knowledge integration across distinct domains (Argyres and Silverman, 2004; Gulati and Puranam 2009; Siggelkow and Levinthal, 2003). We focus on a particularly important type of reorganization: the incorporation of corporate R&D units into independent entities through corporate spinouts (Cirillo et al., 2014; Corley and Gioia, 2004)[1]. Using an inductive approach (Moeen and Agarwal, 2017), we first frame our research questions in the context of extant literature on network dynamics and organizational design. We then examine the patterns of clique-spanning tie formation by 27,483 inventors in the intra-corporate collaboration networks of eight large U.S. information and communication technology (ICT) corporations and their 31 spun-out R&D units during the period 1980–2005.

Our empirical findings show that the reorganization of R&D units through corporate spinouts is associated with an increase in the extent to which corporate inventors collaborate with their peers located in other cliques and other units within the corporate co-invention network. Interestingly, this effect extends beyond inventors directly involved with spun-out units, also affecting their former colleagues remaining in the parent firm. Moreover, contrary to received theories, corporate inventors with high network constraints (or low brokerage) and those with specialized knowledge background are associated

[1]In this study, we refer to corporate spinout as the incorporation of either part or entire R&D unit that remains part of the corporate co-invention network as either a partially or wholly owned subsidiary, a client, or a supplier of the parent firm. By these means, we exclude spinouts or spin-offs as entrepreneurial ventures – i.e., employee ventures that are independent. An example of this definition of corporate spinout is Xerox's R&D unit PARC. Formerly known as Xerox PARC, it is one of the five R&D labs of the Xerox Corporation. In 2002, Xerox spun-out the PARC unit into an independent, wholly owned subsidiary, later known as Palo Alto Research Center Incorporated (or simply PARC Inc.). After the corporate spinout, the unit did not change geographical location, it maintained 230 of its 270 employees (40 employees were laid off), and it remained as part of the Xerox Corporation's co-invention network.

with the highest increase in their likelihood of post-spinout clique-spanning tie formation. Our results also highlight that the formation of clique-spanning ties between parents' and spun-out units' inventors are more frequent when spun-out units employ former parent firms' executives, yet the affiliation of parent firms' executives with the board of spun-out units is not associated with an increase in within-spinout clique-spanning ties. To help identify the precise mechanisms that explain our findings, we also complemented our econometric results with qualitative evidence gathered from interviews with corporate inventors and R&D managers. Our interviews suggest that the spin out of R&D units is associated with an increase in inventors' strategic autonomy—or the right to set research agendas and collaborations (Bailyn, 1985)—and lower coordination and communication costs, which motivate them spontaneously to undertake initiatives, ask for advice, and collect information from other corporate inventors, thus helping them recognize and explore knowledge interdependencies across intra-corporate cliques.

These findings provide novel insights into research streams in intra-corporate collaboration networks evolution. They highlight that the reorganization of a R&D unit through corporate spinout may generate a shock in the entire intra-corporate R&D collaboration network that is associated with an increased connectivity between different groups of corporate inventors, breaking the inertial forces induced by structural embeddedness (Baum et al., 2003). Consistent with our inductive approach, we discuss the theoretical implications of our findings in light of existing theories, to reveal inconsistencies and gaps and to highlight compelling explanations. By doing so, we advance theoretical and empirical understanding of the dynamics of intra-corporate co-invention networks.

## 2. Motivation and research questions

Extant literature on the dynamics of small-world structures in research collaborations has stressed the tendency of collaboration networks to progressively segment into semi-isolated cliques of dense interactions (Rivera et al., 2010; Ahuja et al., 2012). This tendency is driven by structural embeddedness, which constrains the set of partners with which it is feasible to collaborate (Baum et al., 2003). The origins of this inertia can be traced to the fundamental role of collaboration networks in helping R&D employees improve their performance. Networks facilitate access to information (Granovetter, 1974;

Burt, 1992) and enable coordination and collective action (Gulati, 1995; Gulati and Gargiulo, 1999). Since actors (e.g., R&D employees) have a limited amount of time and resources, they face a trade-off between minimizing the risk of defection and opportunism, on one hand, and securing the flexibility to adapt the composition of the network to coordinate new interdependencies, on the other hand (Gargiulo and Benassi, 2000). The establishment of collaborations with familiar ties—such as prior direct ties or their common third parties (Krackhardt, 1998)—is more desirable than the generation of new unfamiliar ties, as the former diminish the uncertainty of actors' knowledge exchanges and enhance their ability to cooperate in the pursuit of a common interest (Gargiulo and Benassi, 2000). Actors linked through ties embedded in a clique are more likely to conform to the norm of reciprocity (Gargiulo and Benassi, 2000). They can trust each other (Gulati, 1995), diminish the risk of opportunism (Granovetter, 1985) and develop common understandings and human capital (Gulati, 1995). The emergence of cliquish structures thus conveys a clear normative order that can help actors share knowledge (Burt, 2001), spur localized learning and exploitation of specialized technologies (Reagans and McEvily, 2003) and thus improve their performance (Podolny and Baron, 1997). Despite these benefits, the establishment of strong social bonds also filters information reaching actors (Uzzi, 1997) and it increases the opportunity costs of initiating new collaborations (Gargiulo and Benassi, 2000). In so doing, a cliquish structure eventually diminishes actors' autonomy to develop the collaborations that are essential to diffuse knowledge and information beyond the boundaries of specific cliques (Gargiulo and Benassi, 2000) and, thus, to explore and recombine novel ideas and knowledge (Cowan and Jonard, 2004; Lazer and Friedman, 2007).

Because network evolution entails strong inertial dynamics, the process that leads to the formation of clique-spanning ties is difficult to understand. Prior studies mostly enquired the evolution of R&D networks in inter-firm (e.g., Powell et al., 2005; Rosenkopf and Padula, 2008) and in regional contexts (e.g., Fleming et al., 2007; Ter Wal, 2013), yet we still know little about whether these findings can be generalized or even extended by analogy to intra-firm collaboration networks where actors, such as R&D employees, are subject to bureaucratic and hierarchical constraints, which should drive their collaboration efforts. Understanding how firms can overcome such inertia is of great importance for managing knowledge recombination in intra-corporate R&D activities. Almost by definition, collaborations that bridge cliques are relatively rare and entail path-breaking behavior. Questions arise: What motivates R&D employees to bridge the gap between isolated cliques in intra-firm collaboration networks? Who engages in such behavior?

Extant literature points to the prevailing systems of incentives and rewards, which in turn depend on the nature of research activity. For example, Gambardella et al. (2015) suggest that when research projects are outside the core businesses of firms, R&D employees should be given full autonomy in project execution (which presumably includes selecting collaborators) and offered monetary premiums. Moreover, individual scientists and engineers who form collaboration links in intra-corporate co-invention networks are subject to hierarchical structures and managerial control; their decisions about the direction and the implementation of research projects—including relevant choices about whom to collaborate with—may be dictated by management (Bailyn, 1985)[2]. The foregoing arguments suggest that any progress in understanding the dynamics of intra-corporate co-invention networks—and more specifically the formation of clique-spanning ties—needs to include consideration of both formal organizational structures and systems of rewards and incentives available to R&D employees. To this aim, in the following we focus our attention on the role that structural reorganizations, and in particular corporate spinouts, have in the formation of clique-spanning ties within intra-corporate co-invention networks.

### *2.1. Structural reorganization through corporate spinouts*

The literature on organizational design has explored how firms can create incentives and opportunities for knowledge recombination in intra-corporate R&D activities (e.g., Sytch and Tatarynowicz, 2014; Tortoriello and Krackhardt, 2010). Changes in the formal organizational structure have acquired particular prominence in this discussion (e.g., Argyres and Silverman, 2004; Siggelkow and Levinthal, 2003): By parsing the organization into smaller, semi-isolated groups, firms may help spur employees'

[2] We gratefully acknowledge the comments of two reviewers who pointed out this important aspect.

exploration in a diverse solution space, encouraging scrutiny of a broader range of solutions (Fang et al., 2010). In other words, some degree of isolation and autonomy has been seen as an environment conducive to the exploration of diverse technological domains, thereby disrupting the inward looking bias prevailing in tightly connected cliques (Ethiraj and Levinthal, 2004). In support of this argument, a body of research on corporate spinouts has reported significant benefits from isolating R&D or business units into formally independent and semi-autonomous organizations. For example, Chesbrough (1998) offers anecdotal evidence of the ability of Xerox's spinouts to experiment with new organizational rules of conduct. Similarly, Corley and Gioia (2004) find that spun-out workers create new meanings through new collaborations, actions, and discussions aimed at resolving the ambiguity of organizational identity created by the spinout event. Cirillo et al. (2014) propose that spun-out inventors can unlearn the expectations of appropriate behavior imposed by the parent organization's code and thus explore distant knowledge. These arguments are also consistent with research on applied psychology that shows how planned organizational changes drive behavioral changes, through the establishment of new cultures of action, interaction processes, social patterns, and networks (Porras and Silvers, 1991).

Anecdotal evidence and managers' opinions provide strong indications that corporate spinouts may be a suitable organizational solution to the problem of reviving the exploratory and entrepreneurial attitude of R&D employees, by acting upon their motivations and incentives. For example, the CEO of Thermo Electron, a large corporation in the field of scientific instruments, explains in this way the benefits that might derive from spinning out R&D and business units (DeSimone et al., 1995):

> (...) *we developed a system that has had an enormous effect on our employees'* attitudes and on the *way they think about new opportunities. We repackaged the equity of some of our more promising businesses and began spinning off separate* (...) *divisions. We call these promising businesses spinouts to distinguish them from the more conventional spin-offs* (...). *For employees and managers involved in the various spinouts, it has provided a new vehicle for ownership. It has given them direct feedback about how their business is viewed by the market and a real incentive to increase its value.* (...) *People at Thermo Electron know they can do well if a spinout is successful.*

(...) *When executives from other companies ask me what they need to do to increase new business activity, the first advice I give them is to change their organizations' basic incentive structures.*

Similarly, T.J. Rodgers, the Chief Executive Officer of Cypress Semiconductors, describes the need for restructuring R&D units through corporate spinouts as follows:

*Cypress planned to grow by funding new ventures* [i.e., corporate spinouts]. *The idea was that when we reached $1 billion in revenue, Cypress would have avoided becoming a big, bureaucratic company, evolving instead into a "federation of entrepreneurs" that still had the just-do-it startup attitude* (…) *Our startup methodology—in which greater than expected losses do not completely wipe out employee gains—is superior to any corporate bonus plan for motivation.*[3]

Notwithstanding these insights, we still know preciously little about the implications of structural changes in R&D activities for the core actors of these processes—i.e., R&D employees. Addressing this gap is important for advancing our understanding of intra-corporate collaboration networks dynamics. Our first research question thus examines the extent to which re-organizations through R&D units spinout are associated with a change in corporate inventors' patterns of tie formation and, more specifically, their propensity to establish clique-spanning ties in the intra-corporate collaboration network.

**Question 1.** What are the patterns of intra-corporate R&D collaborations before and after R&D unit reorganizations through corporate spinouts? How do these patterns differ in terms of corporate R&D employees' propensity to establish intra-corporate clique-spanning ties?

### *2.2. R&D employees' network constraints and knowledge specialization*

The problem of reviving the exploratory and entrepreneurial attitude of R&D employees points also to the need of understanding who engages in clique-spanning collaborations. Prior studies on intra-firm collaboration networks have provided two explanations. The first is that those who already occupy

[3] http://www.cypress.com/documentation/ceo-articles/cypress-startups-history-theory-funding-lessons

brokerage positions between distinct cliques receive unique advantages, such as access to superior information or control over information, thereby benefiting more from new incentives to form clique-spanning collaborations than network-constrained individuals (Burt, 1992). The second explanation is that employees with broad knowledge experience—i.e., generalists—bear lower information asymmetry and opportunity costs than specialized employees in the exploitation of recombinant opportunities across different groups (Melero and Palomeras, 2015). Prior studies thus highlighted that intra-firm collaboration networks are, to some extent, orchestrated by the management through staffing decisions aimed at creating appropriate boundary-spanning structures—centralized inter-unit structures that mediate the transfer of specialized knowledge through a limited number of key individuals, i.e., boundary spanners (Conway, 1997; Tushman and Scanlan, 1981).

Most recent studies, however, have questioned the effectiveness of boundary-spanning structures. Recombining highly complex individual knowledge from specialized expertise areas requires a thorough understanding of interdependencies among different knowledge elements that are difficult to articulate and codify (Hansen, 1999). Developing collaborations across cliques involves transferring high volumes and scope of specialized knowledge, which requires direct participation by non-boundary spanners even in presence of highly capable boundary spanners (Zhao and Anand, 2013). In this respect, two research areas remain understudied. First, imposing to non-brokers (i.e., network-constrained employees) the intermediation of brokers, in order to transfer and share knowledge across cliques, raises the risk that the latter will use their preferential access to information for their own advantage (Burt, 1992). Thus, a major problem of designing appropriate incentives for network-constrained employees may arise. Second, since the emergence of cliquish structures increases the focus of R&D activities in specialized knowledge areas, the intrinsic motivation of specialized employees to directly participate into bridging collaborations also deserves scholarly attention (Zhao and Anand, 2013). Addressing these gaps is important to develop a more fine-grained understanding of how structural changes in R&D activities facilitate knowledge transfers in intra-corporate collaboration networks. Therefore, an ancillary question of our paper regards the implication of corporate spinouts in increasing the propensity of non-brokers and specialized R&D employees to establish clique-spanning ties that recombine knowledge across distinct cliques.

> **Question 2.** Do network-constrained and specialized R&D employees contribute to the generation of clique-spanning ties? Are they associated with increased clique-spanning ties after R&D unit reorganizations through corporate spinouts?

### *2.3. Managerial directives and advices*

Prior research suggests that firms often find it difficult to implement new incentive systems when facing change. Since incentives are context specific, employees have scant knowledge of the kind of behaviors that are likely to be more effective in new contexts, thus making new incentives not credible to them (Kaplan and Henderson, 2005). In this respect, prior literature suggests that corporate executives help shape employees' incentives and provide them with information and political support to implement explorative innovation projects (Karim and Williams, 2012; Kleinbaum and Tushman, 2007). For example, in their study of corporations in the medical sector, Karim and Williams (2012) highlight the contribution of corporate executives in helping employees reduce the uncertainty associated with the initiation of projects across corporate units. Corporate executives hold mental maps of the corporate knowledge network, which help identify synergies across corporate units (Prahalad and Bettis, 1986; Tsai, 2000). Moreover, when they back independent projects, corporate executives provide a credible signal of the strategic value of boundary spanning collaborations, thus motivating employees to engage in more risky behaviors in hope of future career advancements (Kleinbaum and Tushman, 2007).

Notwithstanding these insights, extant research shows that executives face cognitive limits and uncertainty in mapping employees' tasks in new contexts, which limit the organization's ability to structure credible new incentives (Kaplan and Henderson, 2005). This results in the unanswered question of whether change in employees' behavior after structural reorganizations reflects change in employees' motivation, or whether it is the pure result of new managerial directives. With our interest in advancing our understanding of path-breaking intra-corporate network dynamics, our final question investigates this research gap.

> **Question 3.** Do corporate executives play a role in the formation of clique-spanning ties after R&D unit reorganization through corporate spinouts?

## 3. Empirical setting

### *3.1. Sample selection*

For the purposes of this study, we focused on a sample of large U.S. firms operating in the ICT field. In this knowledge-intensive industry, patents offer an effective way to appropriate returns from R&D (Arora et al., 2008) and are widely accepted as a reasonable measure of intra-corporate collaboration networks (Carnabuci and Operti, 2013; Nerkar and Paruchuri, 2005; Paruchuri and Awate, 2017).

To select our sample, we first collected all ICT related patents granted by the USPTO during the period 1980–2005, matching the OECD definition of ICT technologies with the corresponding U.S. Patent Classification (USPC) codes. Then, we ranked all U.S. corporations by the total number of patents they applied in these technological classes and we excluded those operating in automotive and software sectors. Of those remaining, eight U.S. corporations accounted for about 40% of U.S. patenting activities in ICTs during the time-window of this study. They are International Business Machines (IBM), Advanced Micro Devices (AMD), Xerox, Intel, Hewlett-Packard, Lucent, Motorola and Apple. To simplify our data collection and analyses, we focused on these eight corporations.

For each of them, we reviewed news and press releases, using *Factiva* and corporate websites, to identify events of unit or subunit spinouts during the period 1980–2005, according to two criteria. The first was that a unit, or part of it, was voluntarily spun-out by the parent firm into a new incorporated firm, but it remained part of the (holding) corporation. Thus, the parent firm transferred assets to the spun-out unit, either to market untapped technology or divest non-core assets[4]. A total of 97 spun-out units or sub-

[4] For divestiture strategies, we sampled cases in which the parent either temporarily held equity in or signed exclusive agreements with the spinout.

units fit this description. The second criterion was that we could observe inventors employed in spun-out units both before and after spinout events. To this purpose, we used USPTO patent data to identify inventors affiliated with parents and spun-out units. First, we selected all patents applied by our eight corporations at USPTO. Second, we detected inventors' affiliation relying on assignee names in patent data (e.g., Hoisl, 2007) and we selected inventors who successfully applied for at least two patents when they were employed by the parent (within a five-year window before spinout) and at least two patents when employed in a spun-out R&D unit (within a five-year window subsequent to spinout). Observing two patents is a necessary condition for reducing inventor's affiliation bias (see Hoisl, 2007) and for obtaining longitudinal data on the structure of inventors' collaboration network. Following these criteria, we identified 1,002 corporate inventors who were affiliated to 31 corporate R&D units that were spun-out, and 26,481 inventors who were affiliated to other parent units. For the purposes of our study, we focused on these 27,483 inventors[5]. Our final dataset thus consisted of an unbalanced panel with 169,602 observations related to the patenting activities in all USPTO technological classes (i.e., we do not limit our analysis to ICT patents) of 27,483 inventors employed in the eight corporations and 31 spun-out units in 1980-2005[6].

### *3.2. Intra-corporate co-invention networks and cliques*

For each of the eight corporations and their corporate spinouts, we considered all patents granted at USPTO and we reconstructed the collaborative links among their inventors adopting a five-year moving window. Specifically, any pair of inventors *i* and *j*, employed at corporation *C* (or any of its spinouts) at time *t*, were assumed to be linked by a co-invention tie, as long as they co-participated in at least one patent applied for by corporation *C* (or any of its spinouts) in the time window $[t-5, t-1]$[7]. The co-

[5] Yet, for computing intra-corporate co-invention networks we also considered all other inventors that successfully applied for only one patent with our eight corporations at USPTO.
[6] Our sampling criteria create possible sources of bias. For example, we cannot observe inventors who were affiliated to spun-out units but were unproductive, before or after the spinout event. However, patenting is not necessarily associated to spinout success, and in ICTs, many spinouts offer software products. Still, the 66 spinouts excluded from our sample show similar survival rates, strategy, and descriptive statistics to those of our 31 sampled spinouts. For this reasons, we are reasonably confident that our findings are not affected by major biases.
[7] Five years are suitable for studying high-tech firms, which typically engage in long-term innovation projects. The priority year was used to date patents.

invention network of each corporation thus includes all patents (and corresponding inventors) made by both the parent and its corporate spinouts—inventors in corporate spinouts are part of the intra-corporate network from which the corporate spinout derives. Since inventors may have collaborated on more than one patent and the number of co-inventors may differ on each patent, we weighted the collaboration network, by computing the following quantity[8]:

$$w_{ij} = \sum_k \frac{\delta_i^k \delta_j^k}{n_k - 1} \qquad (1)$$

where $\delta_i$ ($\delta_j$) is equal to 1 if inventor *i* (*j*) was a co-author of patent *k*, and $n_k$ is the number of co-inventors of patent *k*. The quantity $w_{ij}$ is thus a measure of the strength of collaboration between inventors *i* and *j* (Newman, 2001). The interaction between two inventors is stronger if they collaborated on many patents and/or they collaborated on patents with a small number of other inventors.

Next, we sought to identify cliques (also called communities or clusters) of inventors within intra-corporate R&D networks. In line with recent network theory (Sytch and Tatarynowicz, 2014) and statistical physics (Clauset et al., 2004), we applied a *modularity* approach to partition the intra-corporate co-invention network of each corporation into constituent cliques[9]. These cliques represent subsets of inventors with high-density of *within-clique* ties, but low-density of *between-clique* ties. In Appendix A we report a detailed description of the methods we used to detect network cliques. As an example, Figure 1 reports the partition of the largest connected component of Xerox's co-invention network in the five-year period 1998-2002. It also illustrates a clique-spanning tie between two distinct cliques of inventors, which was established through a patent made in 2003 by inventors employed in the Xerox's PARC unit, after its spinout in 2002.

[8] Note that single-inventor patents are explicitly excluded from these sums as they do not contribute to any tie.
[9] It is important to stress that our notion of *clique* slightly differs from the one adopted by other authors who studied the formation of bridging ties in small-world networks (e.g., Baum et al., 2003). In those studies, a *clique* is defined as a subset of nodes such that every two distinct nodes in the clique are connected. A drawback of this approach, however, is that the definition is very strict. In this paper, we adopt a notion of *clique* mutuated from the field of statistical physics. In that field, the notion of *community* is used to generalize the idea behind cliques. Loosely speaking, a *community* denotes a collection of strongly overlapping cliques, though all nodes in the *community* are not necessarily connected to each other. For a detailed discussion, see Fortunato (2010) and Newman (2006).

[Insert Figure 1 here]

The importance of investigating the formation of clique-spanning ties is implicitly associated with the idea that those ties allow the recombination of ideas coming from distinct knowledge domains. In other words, the underlying presumption is that cliques tend to specialize in different knowledge areas over time, and that establishing links among them may allow firms to strike a balance between exploitation (via specialization) and exploration (via recombination). For descriptive purposes, we therefore tested the extent to which intra-corporate cliques became increasingly specialized over time in different technological classes at the USPC 3-digit level. In appendix B we report a detailed explanation of the procedure we used. As Figure 2 suggests, the average degree of technological similarity across cliques was systematically and significantly lower than the degree of similarity we would have observed through a random allocation of patents—and thus USPCs—to inventors' cliques. Similarity, cliques similarity also tended to decrease over time for all firms in the sample. Therefore, cliques emerged around specific USPC classes, becoming more homogenous *within* than *between* over time.

[Insert Figure 2 here]

Moreover, in our sample of patents, those involving at least one clique-spanning tie are associated with a greater value, as measured by the number of forward citations obtained in the five years after the grant date (see Table 1). This result is in line with prior contributions on the role of intra-firm knowledge recombination and firm innovation (e.g., Karim and Williams, 2012; Katila and Ahuja, 2002); it highlights the importance of intra-corporate clique-spanning ties for individual and organizational performance (Tushman and Katz, 1980).

[Insert Table 1 here]

### *3.3. Measures*

This study focuses on ties that span cliques of co-inventors in intra-corporate R&D networks. To this aim, we consolidated inventors' patent records to an annual basis. Our unit of analysis is the inventor-year, and all network variables refer to co-invention links recorded in the moving time window [$t-5$, $t-1$]. In what follows, we describe the construction of the dependent and independent variables. Table 2 summarizes the measures for our main variables, while Table 3 provides descriptive and correlation statistics.

[Insert Table 2 and 3 here]

*3.3.1. Dependent Variable*

Our dependent variable captures the extent to which inventor *i* forms links to other intra-corporate cliques. Using the clique partitioning method, we identified the clique in which each inventor was located in the period [$t-5$, $t-1$]. Next, we detected a clique-spanning tie every time inventor *i* co-applied for a patent at time *t* with at least one co-inventor located in a different clique (see Figure 1 for an example). Our dependent variable, *clique-spanning ties*, is the number of clique-spanning ties thereby detected for inventor *i* in year *t*[10].

Moreover, clique-spanning ties can be of two types: ties that connect inventors belonging to different corporate units (i.e., parent-spinout collaborations) and ties that connect inventors in the same corporate unit (i.e., either within parent or within-spinout). As both types contribute to increasing the connectivity of the co-invention network, we also distinguished between the two.

*3.3.2. Independent Variables*

To measure the effects of R&D unit reorganizations, we included several variables that account for direct and indirect mechanisms behind the possible effect of corporate spinouts. Our main independent variable, *corporate spinout*, is a dummy that captures an inventor's affiliation with a corporate spinout at time *t*. Following former literature (Almeida and Kogut, 1999), we used the patent assignee as a proxy for the inventor's affiliation[11]. To estimate inventor affiliation with a spun-out unit, we followed Hoisl (2007) and controlled for the applicant sequence of each inventor, to classify changes in the assignee name as either the parent or a corporate spinout. Detecting inventor affiliation to a corporate spinout can be particularly challenging with regard to patents, because informal R&D collaborations between spinouts

[10] By adopting this specification, we provide a partial control for the endogenous effects driven by corporate strategy. Regardless of whether there is a corporate mandate to connect cliques *A* and *B*, the dependent variable captures the extent to which the inventor *i* connects to other cliques (e.g., *C*, *D*) in the same year.
[11] To this purpose, we used the patent data set developed by Li et al. (2014).

and parents are common and often result in patents assigned to parents, even if they were originally applied for by spun-out units (Hagedoorn, 2003). Thus, we improved the accuracy of our detection of inventor affiliation by correcting a common, unexplored bias in USPTO patent data: If a patent is applied for by a spun-out unit as assignee, and its ownership transfers to the parent firm before the granting date, the USPTO records report the parent firm as the original applicant. To check for and partially correct this bias, we collected additional data on patent assignments by USPTO. A transfer of patent ownership must be filed with the USPTO to be legally binding (Serrano, 2010). Patent assignments acknowledge the rationale of the transfer, buyers and sellers, patent numbers, and date of the agreement. We used the USPTO Patent Assignment Database to extract all patent assignments for which a spinout was the original applicant and the rationale for the assignment was acknowledged as an outright sale (i.e., assignor of interest) from the spun-out unit to its parent, before the patent was granted. Thus, we reduced the potential for misspecification of the inventor's affiliation that could have occurred if patents that inventor *i* worked on had been applied for by the parent firm, after the inventor's unit spinout. Specifically, we coded *corporate spinout* as equal to 1 if inventor *i* was affiliated with a spun-out unit at time *t* (the inventor was affiliated with a R&D unit when this was spun-out), and 0 otherwise.

To test the indirect effects of a corporate spinout on intra-corporate cliques, we included a second independent variable, *same clique post-spinout*, a dummy that identifies those inventors who belong to an intra-corporate clique in year *t* after one or more clique members spun-out with their R&D unit prior to that focal year.

In addition to these key explanatory variables, our estimates also include a series of control variables both at the individual and at the organizational level.

*Individual-level variables*. If a corporate spinout affects the propensity of inventors to establish clique-spanning ties, its effects should vary with two factors generally associated with individual lock-in in cliques. First, we included a measure of network constraint (Burt, 2005), which network studies have used as a proxy for individual embeddedness in collaboration networks (Buskens and van de Rijt, 2008). The network constraint of inventor *i* at time *t*, computed over all co-inventions in [$t-5$, $t-1$], is defined as:

$$Network\ Constraint_{it} = \sum_{j \neq i}\left(p_{ij} + \sum_q p_{iq}\, p_{qj}\right)^2\ i, j\ \neq q, \qquad (2)$$

where $p_{ijt}$ is the intensity of inventor *i*'s collaboration with inventor *j* in [*t*−5, *t*−1], which is defined as:

$$p_{ij} = w_{ij}/\sum_q w_{iq} \qquad (3)$$

where $w_{ijt}$ measures the strength of *i*'s collaboration with *j* in [*t*−5, *t*−1] (see equation 2). The network constraint measure ranges from 0 to 9/8. High values indicate greater embeddedness (or lower brokerage). The network constraint measure is undefined for isolates—that is, inventors with no collaborations in [*t*−5, *t*−1]—and for unproductive inventors with no patents in [*t*−5, *t*−1]. As Buskens and van de Rijt (2008) note, inventors with no connections plausibly suffer higher constraints. Therefore, we followed their approach (see also Lee (2010)) and assigned a value of 2 to network constraint when inventor *i* was either an isolate or had no patents in [*t*−5, *t*−1].

Second, as patenting activities become increasingly specialized within cliques over time (see Figure 2), we also included a measure of inventor's knowledge specialization, which captures the dispersion of inventor *i*'s patenting activity prior to year *t* in different technological fields. We constructed a Herfindahl-type index that captures the dispersion of inventor *i*'s patenting activity prior to year *t* in different technological fields:

$$Knowledge\ specialization_{it} = \left(\sum_{j=1}^{n_{it}} s_{\mathrm{ijt}}^2\right) \qquad (4)$$

where *j* indexes USPC classes, $n_{it}$ is the number of USPC classes inventor *i* has patented until time *t*, and $s_{ijt}$ is the share of inventor *i*'s patents in USPC class *j* until time *t*. The measure ranges from 0 to 1. High values indicate greater specialization.

Other variables at the inventor level included *tenure* (number of years inventor *i* spent in the affiliated organization at time *t*, parent or spinout), *patent stock* (number of patents inventor *i* applied for up to *t*−1), *technological exploration* (number of patents applied by inventor *i* at year *t* in a USPC technological class that is new with respect to previous inventor's records), and *geographical mobility* (dummy equal to 1 if inventor *i* changed residence location in the period [*t*−2, *t*]). As the propensity to form clique-spanning ties also can depend on the centrality in the co-invention network (Fleming et al., 2007), we included a control (*co-inventors*) for the number of co-inventors in the period [$t$−5, $t$−1]. Furthermore, we controlled for the extent to which the inventor produced freelance patents (over which the employer does not claim any right) at year $t$ (*freelance patents*).

*Organizational-level variables*. Using additional data sets, we collected evidence on organizational-level mechanisms that might underlie the effect of corporate spinouts on clique-spanning ties. Research indicates the role of corporate executives in reconfiguring corporate assets (e.g., Helfat and Peteraf, 2015), transferring information, and advising people on intra-corporate brokerage opportunities (e.g., Karim and Williams, 2012). We relied on secondary data (from *CapitalIQ* and *ExecuComp*) and corporate websites to determine whether directors of corporate spinouts were previously employed at the parent firm. In our sample, 13 spinouts employed one executive who had been affiliated with the board of directors of the parent but left that board to join the spinout's board at its incorporation date. No spun-out executive retained his or her former position on the parent firm's board after joining the corporate spinout. Therefore, we measured a dummy variable, *parent executives*, which equals 1 if the inventor $i$ is affiliated at time $t$ with a corporate spinout run by the former parent firm's executives, and 0 otherwise.

Clique-spanning ties may be facilitated by various brokerage opportunities provided by work environments. For example, by co-locating a few inventors from different teams, units, and divisions, corporate spinouts can increase the probability of clique-spanning ties, through pure probability. Thus, we included a control for *co-inventors' co-location* (proportion of corporate co-inventors in the inventor's location at time $t$), the inventor's *clique size* (number of inventors in inventor's clique in [$t$−5, $t$−1]) and *firm size* (number of employees in focal firm in year $t$). In addition, unit reorganizations may increase inventors' likelihood of generating clique-spanning ties, due to staffing decisions. Therefore, we included variables to capture the effects of *new hires* (number of inventors with tenure $< 3$ year in inventor's focal firm in year $t$) and *relocation of corporate inventors* in inventor $i$'s geographical location (proportion of firm's inventors relocated in inventor's two-digit ZIP code from other locations in year $t$). Moreover, with an approach similar to Bidwell and Keller (2014), we measured intra-unit reorganization through *collective turnover* of R&D inventors; this dummy indicates whether 10% or more of the active corporate inventors were relocated in the geographical location of the focal inventor (two-digit ZIP code) from other corporate locations in [$t-1$, $t$]. With this procedure, we identified 34 reorganization events that took place during the period of this study.

### *3.4. Statistical Methods*

Our dependent variable, clique-spanning ties, takes non-negative integer values and exhibits overdispersion. Therefore, we used a panel negative binomial regression model (Cameron and Trivedi, 1998). The Hausman statistic indicated no significant differences between fixed and random effect parameter estimates, so we included inventor random effects.

### *3.5. Results*

We present the results of our main regression model in Table 4. The model specification in Column (0) shows the effects of controls on the extent of clique-spanning ties. In Columns (1)-(4), we include the main independent variables. The significant, positive coefficient of *corporate spinout* suggests that R&D unit reorganization through a corporate spinout is associated with an increase in the likelihood of generating clique-spanning ties for inventors employed in the unit. In Columns (5)-(6), we also show that a corporate spinout is equally associated with the extent to which inventors in spun-out units generate clique-spanning ties with other inventors in the same spun-out unit (i.e., intra-unit) and with inventors in other corporate units (i.e., inter-unit). These latter include collaborations established between spinout's inventors and parent's inventors, after spinout events. In addition, the significant, positive coefficient of *same clique post-spinout* suggests that corporate spinouts are also associated with an increase in clique-spanning ties by inventors who belong to intra-corporate cliques of spun-out inventors. This coefficient is statistically weaker than the effect on spun-out inventors though ($p < 0.05$; two-sided Wald test not shown here). In contrast, intra-unit reorganizations, such as *relocation of corporate inventors* and *collective turnover* of inventors, are not significantly associated with an increase in clique-spanning ties, and their coefficients are significantly lower than that of corporate spinout ($p < 0.001$; one-sided Wald test, not shown here).

All model specifications indicate a significant, negative coefficient for *network constraint* on the likelihood of forming clique-spanning ties across cliques of intra-corporate networks. Inventors with high network constraints are associated with higher clique lock-in than those with low constraints (i.e., brokers). In addition, we find that inventor's knowledge specialization is negatively associated with the likelihood of forming clique-spanning ties in the intra-corporate network.

[Insert Table 4 here]

Accordingly, we included interaction terms between *corporate spinout* and two moderating variables, *network constraint* and *knowledge specialization*. Results (see Columns (3)–(4) in Table 4) reveal a significant, positive interaction ($p < 0.001$) for these variables. Similarly, the interactions between these variables and *same clique post-spinout* produce positive and significant coefficients, in support of the idea that reorganization through a corporate spinout may be associated with a reduction of clique lock-ins in intra-corporate networks. Noting the nonlinearity of our estimation model, we categorized *network constraint* and *knowledge specialization* into quartiles and interpreted the interactions with *corporate spinout* as incidence-rate ratios using the following formulas (Hilbe, 2011):

$$IRR_{Spinout X NextorkConstraint} = \exp[\beta_{Spinout} + \beta_{Spinout X NetworkConstraint}(NetworkConstraint – \text{Mean}(NetworkConstraint))]$$

$$IRR_{Spinout X KnSpecialization} = \exp[\beta_{Spinout} + \beta_{Spinout X KnSpecialization}(KnSpecialization – \text{Mean}(KnSpecialization))]$$

Similarly, we estimated the incidence-rate ratios of the interactions with *same clique post-spinout*. Table 5 contains the incidence-rate ratios, corrected standard errors, and confidence intervals (95%) for the quartile values of *network constraint* and *knowledge breadth*.

[Insert Table 5 here]

The lower boundary of the ratios for higher quartiles of *network constraint* is systematically greater than the upper boundary of the ratios for lower quartiles ($p < 0.01$), thereby confirming the higher estimates for high values of *network constraint*. After R&D unit reorganization through corporate spinout, inventors with a *network constraint* of 0.417 (first quartile, who are less constrained, or brokers) are associated with a 36% increased likelihood of generating clique-spanning ties. In contrast, those with a *network constraint* of 2 (third quartile, who are more constrained, or embedded inventors) are associated with a 348% increased likelihood compared with their pre-spinout period. Similarly, corporate inventors who belong to the same clique of spun-out inventors are associated with a higher increase in their likelihood of generating clique-spanning ties when they are highly constrained in their clique.

Then, in Table 5 the lower boundary of the ratios for higher quartiles of *knowledge specialization* is systematically higher than the higher boundary of the ratios for lower quartiles ($p < 0.01$), thereby confirming the higher estimates for high values of *knowledge specialization*. After R&D unit reorganizations through corporate spinouts, spun-out inventors who are specialized in one technological domain (third quartile) show a 200% higher likelihood of generating clique-spanning ties, whereas those with high breadth of knowledge (first quartile) show only a 92% increase compared with their pre-spinout period. Corporate inventors who belong to the same clique of spun-out inventors also show a higher likelihood of forming clique-spanning ties when they are highly specialized.

To help clarify this point, we ran t-tests on differences in clique-spanning ties between brokers vs. embedded, and generalist vs. specialized inventors in the pre- and post-spinout periods. These tests (see Table 6) show that clique-spanning ties are more frequent for brokers in both in the pre- and post-spinout period. However, network-constrained inventors are associated with the highest increase in clique-spanning ties after spinout events. Similarly, our data reports a higher increase for specialized inventors in the post-spinout period. In contrast, we found no significant increase for generalists.

[Insert Table 6 here]

Further, we considered the role of parent firms' executives. To this aim, we ran a subgroup analysis (Venkatraman, 1989), by distinguishing two groups of corporate spinouts, i.e., *with parent executives* and *without parent executives*[12]. Then we used the main specification to test for the effect of a corporate spinout in each subgroup, as well as the significance of the differences between coefficients across groups. Overall, these results (see Table 7) do not report significant differences in clique-spanning ties'

[12] Testing this mechanism with interactions would require the introduction of three interaction terms, which in turn would introduce multicollinearity issues that might require us to drop *corporate spinout* systematically from the regression estimates. Therefore, we ran subgroup analysis.

formation between spun-out units with and without former parent executives in the board ($p > 0.1$, two-sided Wald test; Columns (2)-(4)). However, significant differences appear when we distinguish between inter-unit and intra-unit clique-spanning ties. In particular, the effect on inter-unit (i.e., parent-spinout) clique-spanning ties is higher when spun-out units appoint former parents' executives in their board than otherwise ($p < 0.001$, two-sided Wald test; Column (6)). In contrast, the effect on intra-unit (e.g., within spun-out units) clique-spanning ties is higher when spun-out units do not appoint former parents' executives in their board. This evidence suggest that former parent firm's executives may not exert significant influence on boundary-spanning collaborations within spun-out units. Similarly, the interaction terms with the two moderating variables, *network constraint* and *knowledge specialization*, are associated with the highest effects in corporate spinouts without parents' executives ($p < 0.05$, two-sided Wald tests; Column (5)).

[Insert Table 7 here]

### *3.6. Qualitative analysis*

The quantitative analyses provided evidence on the association between R&D unit reorganization through corporate spinout and inventors' clique-spanning collaborations. Yet, on the basis of co-patenting data, we could not identify the precise mechanisms that explain these findings. To further interpret the econometric results we elicited comments from people involved in corporate spinout processes. We gathered evidence from two sources: engineers identified as inventors in patent documents of three large corporations operating in the ICT industry and their spun-out units, and executives involved with the founding and eventual management of corporate spinouts[13]. We conducted seven semi-structured phone interviews[14] of about 30 minutes each using a focused interview technique (Merton and Kendall, 1946), with a focus on the processes of unit spinout, structure of collaboration between parent and spun-out

[13] These two categories overlap, in that most inventors had become eventually managing directors of the spun-out units. As one informant explained, "I have sort of drifted through the dark side because I am much more of a manager than inventor now."
[14] We ended our qualitative enquiry after seven interviews because we felt confident that we had reached saturation.

units, corporate patenting policies, and other dimensions related to corporate governance[15]. All interviews were tape-recorded and transcribed. We then performed open coding and engaged in discussions to assess the convergence and divergence in the major empirical concepts that emerged, which we show in Table 8.

[Insert Table 8 here]

## 4. Findings and theoretical implications

In the following, we discuss the theoretical implications of our findings on the evolution of intra-corporate R&D networks after corporate spinouts. Table 9 provides a summary.

[Insert Table 9 here]

> *Finding 1. The reorganization of a R&D unit through a corporate spinout is associated with an increased connectivity of the intra-corporation co-invention network through (i) within-spinout, (ii) between parent-spinout and (iii) within-parent clique-spanning ties.*

In the R&D labs of large ICT corporations, R&D employees are primarily evaluated on their ability to contribute knowledge and ideas useful for the development of new products, processes and services (e.g., Criscuolo et al., 2014; Gittelman and Kogut, 2003). R&D labs have an inventive culture that stimulates creativity and exploration of cutting-edge knowledge in new domains, permits a free flow of information about the scientific achievements of other corporate units, and provides freedom to start new collaborations and explore complementarities across projects. However, collaborations across groups are difficult to establish because of bureaucracy, lengthy procedures, and the long time horizons required for developing and bringing new products to market. In order to ensure alignment and coherence with the organization's overall strategy and capabilities, the strategic autonomy that R&D employees have is typically limited (Bercovitz and Feldman 2008), as they are required to focus their time and efforts on

[15] We first contacted potential interviewees through LinkedIn, with an illustration of the purpose of the interview and an abstract of our research. After scheduling interviews, we emailed the respondents a brief summary of our research findings, to prompt their reactions and views in light of their experiences as inventors or managers of parent firms and spun-out units.

projects with well-defined goals and objectives (Criscuolo et al., 2014). Therefore, R&D employees are put under high levels of pressure to come up with commercially viable inventions and may even be forced to abandon projects mid-way if they do not promise commercial success in the eyes of management[16].

Our interviews suggest that the reorganization of a R&D unit through a corporate spinout may provide R&D employees with a context where they experience higher strategic autonomy–that is, the right to set the research agendas of spun-out units (e.g., Bailyn, 1985)—that motivates them spontaneously to undertake initiatives, ask for advice, and collect information from other corporate inventors, so that they can explore knowledge interdependencies across intra-corporate cliques. In particular, corporate spinouts feature shorter organizational distance between managers and researchers, and simpler, less bureaucratic organizational design. Therefore, they are set to offer better career trajectories to corporate inventors, by making them active managers in the new firm (e.g., Chesbrough, 2003) and by distributing responsibilities and autonomy to freely allocate time and resources (e.g., Gambardella, Panico and Valentini, 2015). These conditions arguably increase the researchers' promotion-based incentives to produce innovation outputs (e.g., Cockburn, Henderson, and Stern, 1999) and their preference to securing flexibility in their network to coordinate new interdependencies to successfully cope with new tasks (e.g., Gargiulo and Benassi, 2000).

Our empirical findings also indicate that the spinout effects spill over to all members of spun-out inventors' cliques, also including those who are employed in the parent firm. In our view, this evidence suggests that corporate spinouts generate a shock in intra-corporate research collaboration dynamics, which loosens clique lock-in effects and contributes to reset cliques boundaries in the intra-corporate research network. Thus, corporate spinouts may feature higher individual autonomy in choosing collaborators in spun-out units and lower coordination and communication costs at the corporate level, which may concur in breaking inventors' clique lock-ins.

[16] We thank an anonymous reviewer to help us articulate this argument.

*Finding 2. Corporate inventors with (i) high network constraints (or low brokerage) and those with (ii) specialized knowledge background are associated with the highest increase in their likelihood of clique-spanning tie formation post-spinout.*

After the spinouts of their corporate units, inventors that suffer higher network constraints (embedded inventors) are associated with a higher increase in their propensity to form clique-spanning ties than those occupying brokering positions (brokers). A similar increase is observed for inventors with a narrow knowledge background (specialized inventors), compared with inventors with broad individual technological experience (generalists). These findings do not conform to existing literature. In particular, research has long considered the effectiveness of boundary-spanning structures in dealing with the opportunity costs and uncertainty associated with the recombination of knowledge across organizational and technological boundaries (Burt, 1992). In contrast to this research tradition, our findings suggest that, after structural changes in R&D units, network-constrained and specialized inventors may increase their contribution to the formation of clique-spanning ties relatively more than brokers and generalists. Developing clique-spanning ties involves transferring high volumes and scope of specialized knowledge. Network-constrained inventors hold a thorough understanding of their clique's collective and tacit knowledge, that is, knowledge embedded among clique members about how to coordinate, distribute, and recombine clique's knowledge. In addition, specialists in particular technologies cannot predictably enhance their innovation performance based solely on the knowledge they possess; they must interact—more than inventors who have broad knowledge backgrounds—with other specialists who possess different knowledge (Nickerson and Zenger, 2004). The increased autonomy in establishing collaborations may be associated with an increased intrinsic motivation to share clique-specific tacit knowledge in clique-spanning collaborations (Zhao and Anand, 2013). Indeed, as opposed to contexts where collaborations are orchestrated by the management, specialized inventors may choose to avoid the intermediation of brokers and thus directly appropriate the value that results from combining their specific knowledge in clique-spanning collaborations. Therefore, corporate spinouts may feature contexts where the opportunity costs of initiating non-redundant network ties are reduced.

Similar effects may not necessarily hold for inventors who occupy brokerage positions and for generalists, who may already enjoy a certain degree of autonomy regardless spinout events (Burt, 1992; Melero and Palomeras, 2015). Our results thus offer support, across a large sample, to Zhao and Anand's (2013) intuition about collective bridges. Corporate spinouts may configure shorter, more direct inter-cliques links for the transfer of complex, specialized knowledge, also providing the advantage of reducing task overload on brokerage positions (Zhao and Anand, 2013). Viewed holistically, Findings 1 and 2 thus possibly uncover corporate spinouts as compelling knowledge transfer structures, which may be more efficient in transferring complex, specialized knowledge within intra-corporate R&D networks.

> *Finding 3. When they join the spun-out R&D unit's board, the former parent firm's executives facilitate the formation of parent-spinout (i.e., inter-unit) clique-spanning collaborations. However, they are not associated with the emergence of within-spinout (i.e., intra-unit) clique-spanning collaborations.*

Our interviews suggested that corporate spinouts enable frequent interactions between inventors and managers, allowing inventors to update managers on new idea generation processes and give managers the opportunity to advise inventors about where to look for complementary knowledge and projects in the intra-corporate network. These findings enrich our understanding on the likely mechanisms through which corporate spinouts may influence inventors' collaborative behavior. Our results are twofold. First, corporate executives may spur inter-unit clique-spanning activities and create more cohesive intra-corporate collaborative networks. Executives hold mental maps that align with the strategic positioning of their corporations (Prahalad and Bettis, 1986), their corporate projects and products, allowing them to identify synergies across strategically related units (Tsai, 2000) and to provide important information about where corporate knowledge resides and who can exploit it. While inventors know fairly well their direct collaborators and their immediate neighbors, they are likely to have only limited and imperfect information of the global corporate co-invention network. The mental maps provided by corporate executives thus can play a fundamental role in helping spun-out inventors navigate the network and search relevant complementary knowledge (e.g., Dodds et al., 2003).

Second, prior literature suggested that parent firm's executives exercise an important monitoring role on the strategic direction of spun-out units (Semadeni and Cannella, 2011). Corporate senior managers hold a formal responsibility in shaping the incentives of corporate inventors to get involved in boundary-spanning collaborations (Karim and Williams, 2012) and they are responsible for appointing key actors—i.e., brokers—to linking roles in the intra-corporate network (Kleinbaum and Tushman, 2007). In contrast to these mechanisms, our empirical evidence points to the importance of collective bridges (Zhao and Anand, 2013) and shows that the formation of within-spinout clique-spanning collaborations is more frequent in contexts where former parent firm's senior management does not influence the strategic orientation of the spun-out R&D unit. Viewed together, Findings 2 and 3 imply that the clique-spanning collaborations patterns that we observe do not necessarily reflect managerial directives or spinout staffing decisions.

## 5. Conclusions

Firms' capabilities to recombine knowledge fundamentally depends on their ability to integrate and build ties across loosely connected intra-corporate cliques of inventors (Katila and Ahuja, 2002; Tsai, 2000). Research on the organizational solutions that enable the establishment of those ties so far has been limited and generic; there is a need for theory to understand the mechanisms that underlie the formation of clique-spanning ties within corporate boundaries. This study offers a starting point by conceptualizing reorganizations of R&D units through corporate spinouts as a particular type of organizational innovation that can help increase connectivity of the entire corporate co-invention network—i.e., divide to connect. In this regard, the study contributes to further our understanding of the micro-foundations of network dynamics (Ahuja et al., 2012; Gulati et al., 2012), by emphasizing the crucial role of individual agency, incentives and motivations in breaking the inertial forces driving collaboration in intra-firm research networks.

Our study thus contributes to the literature on the emergence and evolution of small world networks. While network structure imposes constraints on individuals, driving them to search for partners among past acquaintances and in their immediate network neighborhood, the resulting inertia in network evolution can be broken. However, our findings seem to suggest that individuals will search for distant targets only when they have sufficient and proper incentives to do so. It shows that, in the context of co-invention networks, providing strategic autonomy and removing various bureaucratic and hierarchical constraints may give inventors the correct incentives to overcome structural embeddedness and to activate distant collaborations. More generally, the structure and the evolution of a network can only be interpreted and understood in the light of the motivations, actions and strategies of individuals embedded in that network (Dodds et al.  2003). Thus our results suggest that firms should not focus solely on boundary spanners, but they should also tailor their micro-level human capital strategies to include network-constrained and specialized inventors, who become reliable sources of innovations that span distinct knowledge cliques in the corporation. The scope of individual activities thus reveals some room to maneuver in corporate co-invention networks.

In our attempt to explore these mechanisms, several limitations and alternative explanations arise. First, collaboration across cliques may result from firm's agency or managerial staffing decisions that we did not observe. Managers in corporate spinouts may just create more heterogeneous teams to match the different strategic objectives of spun-out units. In our study, we reduced this potential bias by including controls on new hires, relocation of corporate inventors and collective turnover. In addition, our results show that a corporate spinout is equally increasing the extent to which inventors in spun-out units generate clique-spanning ties with inventors in other corporate units (e.g., the parent) post-spinout events.

Second, we cannot rule out alternative explanations based on the opportunities, costs, and inventors' personal intrinsic motivations to initiate or join bridging collaborations. Collaborations across cliques also may result from individual incentive dimensions that we could not capture. Moreover, some of the theoretical constructs we used to interpret our findings—e.g., strategic autonomy—are very difficult to measure. Even though we addressed these issues by eliciting the views of managers and inventors, the sample of individuals interviewed is admittedly small.

Third, our findings are based on a limited sample of large corporations in a single industry and they are partly based on patent data. Apart from the usual caveats, this type of data does not capture all relationships among inventors and their contents. Hence, we cannot make strong claims about the generalizability of our results, or the extent to which they apply to different contexts.

Fourth, we did not consider parent firms' motivations to initiate corporate spinouts or the cost associated with these strategies. In this respect, though, it was not our purpose to prove causality, or to show that reorganizations through corporate spinouts are better than other solutions. Rather, our empirical strategy aimed to show that, possibly correcting for alternative mechanisms, corporate spinouts might be a compelling mechanism to facilitate collaboration among intra-corporate cliques of inventors.

Our results thus call for future research to examine the individual and organizational mechanisms that generate these effects. New theory development may extend our understanding of the boundary conditions to the effectiveness of R&D units reorganizations vis-à-vis boundary spanner structures. Currently, intra-firm collaboration networks are to some extent orchestrated by the management (Kleinbaum and Tushman, 2007; Lee, 2010) and boundary spanner structures have been considered as an effective strategy for knowledge transfer within organizations (Burt, 1992). Our study suggests that the spinout of a corporate R&D unit may be equally important to the evolution of clique-spanning collaborations. As regards, research should explore the extent to which reorganizations through corporate spinouts may complement or substitute for boundary-spanning structures, as well as their relative efficiency in transferring and recombining complex knowledge.

Finally, our findings pointed to strategic autonomy as a mechanism to break structural embeddedness in intra-corporate R&D networks. Future research seeking to develop new explanations of the underlying organizational mechanisms may focus on whether and how corporate spinouts help the development of a new normative order in intra-corporate R&D networks. Specifically, in understanding the sources of disruption in collaboration dynamics, future research needs to relate structural reorganizations with the development of new common understandings, norm of reciprocity and trust between distinct cliques of corporate inventors. To this aim, additional research could also refine the content of structural reorganizations and derive better empirical measures.

With this study, we hope to have contributed to build a stronger link between empirical research on structural changes and the emergence of small worlds. Despite the ubiquitous nature of the small world structure, the mechanisms that explain its dynamic evolution, particularly the formation of clique-spanning ties, may vary according to the context examined. In the context of intra-corporate co-invention networks, the reorganization of R&D units through corporate spinouts may play a fundamental role.

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**Table 1. Clique-spanning ties (Fast-Greedy community partitioning method) and patent value [a]**

| Group: | N | Mean | Std. Err. | Std. Dev. | 95% C.I. |
|---|---|---|---|---|---|
| Patents with clique-spanning ties | 15,225 | 1.1139 | 0.032 | 4.057 | [1.009, 1.178] |
| Patents without clique-spanning ties | 29,853 | 1.0050 | 0.018 | 3.192 | [0.968, 1.041] |
| Mean Difference | | + 0.1089*** | 0.034 | | [0.040, 0.177] |

[a] Patent value is measured by the number of forward citations received by a patent in [*t*, *t*+5] adjusted by the average citations received by any patent in that same year and with that same patent class at USPTO (Hall et al. 2001).
******* p<0.001

**Table 2. Description of main variables**

| Variable | Measure |
|---|---|
| Clique-spanning ties | No. of co-patenting ties in year *t* by inventor with others located in other intra-corporate cliques. |
| Clique-spanning ties (intra-unit) | No. of co-patenting ties in year *t* by inventor with others located in other intra-corporate cliques and same corporate unit. |
| Clique-spanning ties (inter-unit) | No. of co-patenting ties in year *t* by inventor with others located in other intra-corporate cliques and different corporate unit. |
| Corporate spinout | 1{inventor is affiliated in year *t* to a corporate spinout}; 0 otherwise. |
| Same clique post-spinout | 1{inventor belongs in year *t* to the same intra-corporate clique of a spun-out inventor}; 0 otherwise. |
| Network constraint | Burt network constraint. A value of 2 was assigned to inventors without collaborators (isolates) and for inventors with no patents in [*t*–5, *t*–1]. |
| Knowledge specialization | Herfindahl index of distribution of inventor's patents across USPCs prior year *t*. |
| Tenure | No. of years since first patent at the focal firm at year *t*. |
| Patent stock | No. of patents applied in year *t*. |
| Technological exploration | No. of patents applied in new USPC classes until year *t*. |
| Geographical mobility | 1{inventor changed residence location in [*t*-2, *t*]}; 0 otherwise. |
| Co-inventors | No. of co-inventors in [*t*-5, *t*-1]. |
| Freelance patents | No. of patents awarder to the inventor in year *t* without assignee. |
| Parent executives | 1{inventor's spinout hires former parent executives}; 0 otherwise. |
| Co-inventors co-location | Proportion of co-inventors that locate in inventor's ZIP code (2 digits) in year *t*. |
| Clique size | No. of inventors in inventor's clique with patent records in [*t*-5, *t*-1]. |
| Firm size | No. of employees in focal firm in year *t*. |
| New hires | No. of inventors with tenure < 3 year in inventor's focal firm in year *t*. |
| Relocation of corporate inventors | Proportion of firm's inventors relocated in inventor's ZIP code (2 digits) from other locations in year *t*. |
| Collective turnover | 1{10% or more of the active corporate inventors were re-located in inventor's geographical location in years [*t* – 1, *t*]}; 0 otherwise. |

**Table 3. Descriptive statistics and correlations**

| | | Mean | SD | Min | Max | *v1* | *v2* | *v3* | *v4* | *v5* | *v6* | *v7* | *v8* | *v9* | *v10* | *v11* | *v12* | *v13* | *v14* | *v15* | *v16* | *v17* | *v18* | *v19* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *v1* | Clique-spanning ties | 0.310 | 1.002 | 0 | 23 | | | | | | | | | | | | | | | | | | | |
| *v2* | Clique-spanning ties (intra-unit) | 0.219 | 0.770 | 0 | 17 | .92 | | | | | | | | | | | | | | | | | | |
| *v3* | Clique-spanning ties (inter-unit) | 0.090 | 0.419 | 0 | 17 | .70 | .36 | | | | | | | | | | | | | | | | | |
| *v4* | Corporate spinout | 0.015 | . | 0 | 1 | .02 | .01 | .04 | | | | | | | | | | | | | | | | |
| *v5* | Same clique post-spinout | 0.276 | . | 0 | 1 | .05 | .05 | .02 | -.08 | | | | | | | | | | | | | | | |
| *v6* | Network constraint | 0.982 | 0.683 | 0.019 | 2 | -.21 | -.19 | -.14 | -.05 | -.15 | | | | | | | | | | | | | | |
| *v7* | Knowledge specialization | 0.683 | 0.308 | 0.046 | 1 | -.20 | -.18 | -.14 | -.10 | -.15 | .44 | | | | | | | | | | | | | |
| *v8* | Tenure | 4.110 | 4.210 | 0 | 30 | .09 | .09 | .04 | -.08 | .26 | -.23 | -.39 | | | | | | | | | | | | |
| *v9* | Patent stock | 1.139 | 2.106 | 0 | 192 | .34 | .30 | .26 | .06 | .01 | -.08 | -.19 | -.00 | | | | | | | | | | | |
| *v10* | Technological exploration | 0.641 | 1.722 | 0 | 40 | .09 | .05 | .12 | .24 | .02 | -.08 | -.35 | .13 | .19 | | | | | | | | | | |
| *v11* | Geographical mobility | 0.007 | . | 0 | 1 | .01 | .01 | .01 | .01 | .05 | -.01 | -.06 | .05 | .02 | .08 | | | | | | | | | |
| *v12* | Co-inventors | 1.605 | 2.153 | 0 | 26 | .35 | .33 | .24 | .03 | .00 | -.03 | -.16 | -.03 | .31 | .07 | .02 | | | | | | | | |
| *v13* | Freelance patents | 0.003 | 0.064 | 0 | 7 | .02 | .01 | .03 | .05 | -.01 | -.01 | -.04 | -.00 | .11 | .07 | .02 | .00 | | | | | | | |
| *v14* | Parent executives | 0.011 | . | 0 | 1 | .02 | .00 | .04 | .87 | -.07 | -.04 | -.09 | -.07 | .04 | .21 | .01 | .02 | .05 | | | | | | |
| *v15* | Co-inventors co-location | 0.011 | 0.104 | 0 | 1 | .02 | -.01 | .00 | .86 | -.06 | -.04 | -.09 | -.07 | .05 | .21 | .01 | .02 | .05 | .88 | | | | | |
| *v16* | ln(Clique size) | 0.011 | 0.105 | 0 | 1 | .02 | .16 | .11 | .87 | -.07 | -.04 | -.09 | -.07 | .05 | .21 | .01 | .02 | .05 | .92 | .87 | | | | |
| *v17* | ln(Firm size) | 0.134 | 0.290 | 0 | 1 | -.00 | .02 | -.06 | -.03 | -.19 | .40 | .21 | -.35 | .20 | -.03 | -.03 | .25 | -.00 | -.03 | -.03 | -.03 | | | |
| *v18* | New hires | 3.309 | 2.329 | 0 | 7.310 | .17 | .15 | .11 | .04 | .21 | -.71 | -.41 | .21 | .08 | .12 | .03 | .04 | .01 | .03 | .03 | .03 | -.37 | | |
| *v19* | Relocation of corporate inventors | 11.961 | 0.849 | 3.332 | 12.913 | -.01 | -.01 | .00 | -.35 | .17 | .01 | .04 | .05 | -.09 | -.18 | -.01 | .01 | -.02 | -.27 | -.24 | -.30 | -.02 | .05 | |
| *v20* | Collective turnover | 1.694 | . | 0 | 25 | .16 | -.02 | -.01 | .03 | -.04 | .04 | -.12 | -.02 | .26 | .08 | .02 | .40 | .00 | .04 | .03 | .03 | .22 | -.05 | -.08 |

Note. N = 169,602. All correlations above |.02| are significant at $p < 0.01$. For Network Constraint, a value of 2 was assigned to inventors without collaborators (isolates) and for inventors with no patents in $[t - 5, t - 1]$.

**Table 4. Random effects negative binomial models**

| DEPENDENT VARIABLE: | Clique-spanning Ties (all) | Clique-spanning Ties (all) | Clique-spanning Ties (all) | Clique-spanning Ties (all) | Clique-spanning Ties (all) | Clique-spanning Ties (intra-unit) | Clique-spanning Ties (inter-unit) |
|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| INDEPENDENT VARIABLES: | | | | | | | |
| Corporate spinout | | 0.181** | 0.580*** | 0.437*** | 0.735*** | 0.782*** | 0.670*** |
| | | (0.061) | (0.072) | (0.076) | (0.083) | (0.102) | (0.115) |
| Same clique post-spinout | | 0.100*** | 0.365*** | 0.241*** | 0.421*** | 0.420*** | 0.411*** |
| | | (0.017) | (0.022) | (0.020) | (0.023) | (0.026) | (0.037) |
| Network constraint | | -1.168*** | -1.364*** | -1.146*** | -1.324*** | -1.282*** | -1.316*** |
| | | (0.021) | (0.024) | (0.021) | (0.024) | (0.027) | (0.037) |
| Knowledge specialization | | -1.337*** | -1.297*** | -1.587*** | -1.473*** | -1.427*** | -1.452*** |
| | | (0.031) | (0.031) | (0.037) | (0.037) | (0.042) | (0.058) |
| Corporate spinout X Network constraint | | | 0.820*** | | 0.751*** | 0.676*** | 0.781*** |
| | | | (0.093) | | (0.094) | (0.119) | (0.128) |
| Corporate spinout X Knowledge specialization | | | | 0.969*** | 0.731*** | 0.773** | 0.659* |
| | | | | (0.195) | (0.196) | (0.242) | (0.264) |
| Same clique post-spinout X Network constraint | | | 0.581*** | | 0.501*** | 0.496*** | 0.454*** |
| | | | (0.033) | | (0.034) | (0.038) | (0.055) |
| Same clique post-spinout X Knowledge specialization | | | | 0.737*** | 0.495*** | 0.479*** | 0.461*** |
| | | | | (0.057) | (0.059) | (0.067) | (0.093) |
| Tenure | 0.030*** | -0.015*** | -0.015*** | -0.014*** | -0.014*** | -0.011*** | -0.024*** |
| | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.003) |
| Patent stock | 0.122*** | 0.112*** | 0.112*** | 0.113*** | 0.112*** | 0.123*** | 0.111*** |
| | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.003) |
| Technological exploration | -0.025*** | -0.054*** | -0.053*** | -0.051*** | -0.051*** | -0.063*** | -0.022*** |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.004) | (0.005) |
| Geographical Mobility | 0.106 | 0.087 | 0.078 | 0.092 | 0.083 | 0.105 | 0.024 |
| | (0.070) | (0.069) | (0.069) | (0.069) | (0.070) | (0.080) | (0.104) |
| Co-inventors | 0.250*** | 0.244*** | 0.246*** | 0.245*** | 0.246*** | 0.254*** | 0.261*** |
| | (0.002) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.004) |
| Freelance patents | -0.257** | -0.354*** | -0.370*** | -0.352*** | -0.367*** | -0.471*** | -0.243* |
| | (0.081) | (0.073) | (0.073) | (0.073) | (0.073) | (0.096) | (0.097) |
| Co-inventors co-location | -0.100*** | 0.271*** | 0.364*** | 0.305*** | 0.374*** | 0.297*** | 0.345*** |
| | (0.029) | (0.028) | (0.029) | (0.028) | (0.029) | (0.033) | (0.044) |
| ln(Clique size) | 0.239*** | -0.019*** | -0.026*** | -0.021*** | -0.026*** | -0.024*** | -0.036*** |
| | (0.004) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) | (0.009) |
| ln(Firm size) | -0.038* | 0.060** | 0.067*** | 0.069*** | 0.072*** | 0.146*** | 0.046 |
| | (0.015) | (0.019) | (0.020) | (0.020) | (0.020) | (0.025) | (0.027) |
| New hires | 0.097*** | 0.086*** | 0.083*** | 0.084*** | 0.083*** | 0.079*** | 0.075*** |
| | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.003) | (0.004) |
| Relocation of corporate inventors | -0.438 | 0.623 | 0.497 | 0.605 | 0.503 | -0.266 | 1.008 |
| | (0.479) | (0.440) | (0.450) | (0.444) | (0.452) | (0.619) | (0.537) |
| Collective turnover | -0.043** | -0.009 | -0.009 | -0.010 | -0.009 | 0.005 | -0.068** |
| | (0.014) | (0.014) | (0.014) | (0.014) | (0.014) | (0.015) | (0.021) |
| Corporation dummies | included | included | included | included | included | included | included |
| Inventor random effects | included | included | included | included | included | included | included |
| Constant | -3.120*** | -1.434*** | -1.396*** | -1.428*** | -1.390*** | -2.328*** | -1.143** |
| | (0.186) | (0.248) | (0.251) | (0.252) | (0.254) | (0.326) | (0.352) |
| N (inventor–year) | 169,602 | 169,602 | 169,602 | 169,602 | 169,602 | 169,602 | 169,602 |
| Log-likelihood | -90,221 | -86,635 | -86,463 | -86,546 | -86,424 | -70,885 | -39,716 |

*Note*. Standard errors (in parentheses) estimated from the observed information matrix (OIM).
*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

**Table 5. Interpretation of interactions: Risk ratios**

| Corporate spinout × Network constraint | | | | | Corporate spinout × Knowledge specialization | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Network constraint | Quartile | IRR | Std.err. | 95% CI | Knowledge specialization | Quartile | IRR | Std.err. | 95% CI |
| 2 | 75% | 4,480 | 0,232 | [2,841; 7,064] | 1 | 75% | 3,004 | 0,249 | [1,845; 4,890] |
| 0.77 | 50% | 1,779 | 0,129 | [1,381; 2,290] | 0.625 | 50% | 2,284 | 0,180 | [1,607; 3,245] |
| 0.417 | 25% | 1,364 | 0,104 | [1,113; 1,673] | 0.389 | 25% | 1,921 | 0,138 | [1,467; 2,518] |
| **Same clique post-spinout × Network constraint** | | | | | **Same clique post-spinout × Knowledge specialization** | | | | |
| Network constraint | Quartile | IRR | Std.err. | 95% CI | Knowledge specialization | Quartile | IRR | Std.err. | 95% CI |
| 2 | 75% | 2,537 | 0,146 | [1,906; 3,377] | 1 | 75% | 1,951 | 0,069 | [1,703; 2,234] |
| 0.77 | 50% | 1,370 | 0,086 | [1,158; 1,621] | 0.625 | 50% | 1,620 | 0,049 | [1,473; 1,782] |
| 0.417 | 25% | 1,148 | 0,064 | [1,013; 1,300] | 0.389 | 25% | 1,441 | 0,037 | [1,342; 1,549] |

**Table 6. T-test on clique-spanning ties pre- and post- spinout**

| | *Pre-spinout* | *Post-spinout* | $\beta(post) - \beta(pre) > 0$ |
|---|---|---|---|
| *Broker* inventors [a] | 0.446 | 0.527 | + 0.081 |
| *Embedded* inventors [a] | 0.177 | 0.446 | + 0.269*** |
| $\beta(Broker) - \beta(Embedded) > 0$ | + 0.268*** | + 0.080* | |
| | | | |
| *Generalist* inventors [b] | 0.485 | 0.489 | + 0.004 |
| *Specialized* inventors [b] | 0.167 | 0.521 | + 0.354*** |
| $\beta(Generalist) - \beta(Specialized) > 0$ | + 0.318*** | − 0.032 | |

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

[a] An inventor is coded as *embedded* if her *burt constraint* > median(*burt constraint*) in corporate/year, and as *broker* otherwise.

[b] An inventor is coded as *specialized* if her *knowledge specialization* > median(*knowledge specialization*) in corporate/year, and as *generalist* otherwise.

**Table 7. Random effects negative binomial models**

| DEPENDENT VARIABLE: | Clique-spanning ties (all) | Clique-spanning ties (all) | Clique-spanning ties (all) | Clique-spanning ties (all) | Clique-spanning ties (intra-unit) | Clique-spanning ties (inter-unit) |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| INDEPENDENT VARIABLES: | | | | | | |
| Corporate spinout with parent executives | 0.227*** | 0.472*** | 0.399*** | 0.594*** | 0.463*** | 0.757*** |
| | (0.065) | (0.078) | (0.089) | (0.095) | (0.123) | (0.124) |
| Corporate spinout w/o parent executives | 0.026 | 0.485*** | 0.257* | 0.689*** | 1.098*** | 0.049 |
| | (0.099) | (0.124) | (0.117) | (0.138) | (0.156) | (0.223) |
| Same clique post-spinout | 0.101*** | 0.100*** | 0.100*** | 0.099*** | 0.104*** | 0.116*** |
| | (0.017) | (0.017) | (0.017) | (0.017) | (0.020) | (0.027) |
| Network constraint | -1.168*** | -1.188*** | -1.168*** | -1.186*** | -1.143*** | -1.198*** |
| | (0.021) | (0.021) | (0.021) | (0.021) | (0.023) | (0.033) |
| Knowledge specialization | -1.336*** | -1.329*** | -1.350*** | -1.341*** | -1.299*** | -1.329*** |
| | (0.031) | (0.031) | (0.031) | (0.031) | (0.035) | (0.049) |
| Corporate spinout with parent executives X Network constraint | | 0.543*** | | 0.509*** | 0.408** | 0.629*** |
| | | (0.107) | | (0.108) | (0.143) | (0.136) |
| Corporate spinout with parent executives X Knowledge specialization | | | 0.669** | 0.533* | 0.302 | 0.660* |
| | | | (0.228) | (0.231) | (0.296) | (0.294) |
| Corporate spinout w/o parent executives X Network constraint | | 0.983*** | | 0.959*** | 1.012*** | 0.747* |
| | | (0.182) | | (0.185) | (0.213) | (0.320) |
| Corporate spinout w/o parent executives X Knowledge specialization | | | 1.241*** | 1.139** | 1.412** | 1.357* |
| | | | (0.373) | (0.370) | (0.443) | (0.561) |
| Tenure | -0.015*** | -0.016*** | -0.016*** | -0.016*** | -0.012*** | -0.025*** |
| | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.003) |
| Patent stock | 0.113*** | 0.113*** | 0.113*** | 0.112*** | 0.123*** | 0.112*** |
| | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.003) |
| Technological exploration | -0.054*** | -0.053*** | -0.052*** | -0.052*** | -0.064*** | -0.024*** |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.004) | (0.005) |
| Geographical Mobility | 0.086 | 0.087 | 0.085 | 0.085 | 0.109 | 0.027 |
| | (0.069) | (0.069) | (0.069) | (0.069) | (0.080) | (0.104) |
| Co-inventors | 0.244*** | 0.244*** | 0.244*** | 0.244*** | 0.252*** | 0.259*** |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.004) |
| Freelance patents | -0.355*** | -0.354*** | -0.355*** | -0.354*** | -0.459*** | -0.239* |
| | (0.073) | (0.073) | (0.073) | (0.073) | (0.096) | (0.097) |
| Co-inventors co-location | 0.271*** | 0.280*** | 0.271*** | 0.279*** | 0.201*** | 0.268*** |
| | (0.028) | (0.028) | (0.028) | (0.028) | (0.032) | (0.043) |
| ln(Clique size) | -0.019*** | -0.020*** | -0.019*** | -0.021*** | -0.019** | -0.030*** |
| | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) | (0.009) |
| ln(Firm size) | 0.053** | 0.047* | 0.045* | 0.042* | 0.123*** | 0.001 |
| | (0.020) | (0.020) | (0.020) | (0.020) | (0.025) | (0.027) |
| New hires | 0.086*** | 0.085*** | 0.085*** | 0.085*** | 0.081*** | 0.078*** |
| | (0.002) | (0.002) | (0.002) | (0.002) | (0.003) | (0.004) |
| Relocation of corporate inventors | 0.622 | 0.613 | 0.610 | 0.606 | -0.103 | 1.036 |
| | (0.440) | (0.441) | (0.442) | (0.442) | (0.606) | (0.530) |
| Collective turnover | -0.009 | -0.009 | -0.009 | -0.008 | 0.006 | -0.066** |
| | (0.014) | (0.014) | (0.014) | (0.014) | (0.015) | (0.021) |
| Corporation dummies | included | included | included | included | included | included |
| Inventor random effects | included | included | included | included | included | included |
| Constant | -1.348*** | -1.260*** | -1.237*** | -1.176*** | -2.205*** | -0.728* |
| | (0.250) | (0.251) | (0.253) | (0.253) | (0.324) | (0.347) |
| N (inventor–year) | 169,602 | 169,602 | 169,602 | 169,602 | 169,602 | 169,602 |
| Log-likelihood | -86,633 | -86,610 | -86,623 | -86,603 | -71,023 | -39,753 |
| | *Signs and p-values (two-sided test) for coefficients differences* | | | | | |
| β(Corp. spin. with p. exec.) - β(Corp. spin. w/o p. exec.) = 0 | (+) .042 | (−) .922 | (+) .292 | (−) .545 | (−) .001 | (+) .004 |

*Note*. Standard errors (in parentheses) estimated from the observed information matrix (OIM).
*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

**Table 8. Interviews open coding**

| Themes | Selection of representative quotes | Codes |
|---|---|---|
| The emergence of cliquish structures in intra-corporate R&D collaboration networks | "The [parent's] lab was pretty good actually, but it was much more bureaucratic. You are much more constrained to your own project" (*parent's executive*)<br>"The internal large context of the parent organization will limit them [i.e., inventors] to pursue new ideas, because there are other priorities, there is no budget to pursue them, or all kind of internal organizational reasons why the organization constraints them…" (*corporate spinout's inventor and manager*) | Organization control over individual efforts |
| | "They [corporate inventors] have a limited spirit because of the organizational context" (*parent's executive*)<br>"We tried for years to have some of the ideas that were in these technologies get into the [parent] software division. Many of them have gone in there but [the parent] didn't really have a huge success in that... Some of these technologies, of these applications, were really applications in which [the parent] didn't have a current commercial activity and it was really important to create a new vehicle to exploit our opportunities" (*parent's inventor*) | Lack of strategic autonomy |
| | "[The R&D lab] had an academic environment, and in that academic environment people have a focus into their discipline and their goal is to advance the discipline, to push the state of the art" (*parent's inventor*)<br>"It was a bit unusual that I actually collaborated across the unit. I never thought of constraints. The main thing is, you know, it is a bunch of academics publishing in a certain area, so you tend to work with people that are publishing in the same" (*parent's inventor*)<br>"So, one group [i.e., clique] included linguistics, text modellings, speeches, and graphics. Another group [i.e., clique] was more AI. What you are seeing is mostly the speeches, graphics and linguistics crowd. ... And interestingly also, people on the left were on the south side of the building and people on the right were on the north side of the building" (*parent's inventor*) | Within-clique knowledge specialization |
| The impact of R&D unit reorganization through corporate spinout on intra-corporate R&D collaborations | "You are actually less constrained in thinking, and clearly, again, the spinout has a much more focused goal usually, but there is a lot of more responsibility… you are less constrained in your thinking for sure" (*corporate spinout's inventor and manager*)<br>"The thing that has changed seems to be that the company is clearly more focused. We are focused on a certain goal to achieve" (*corporate spinout's executive*)<br>"The spinout forces [inventors] to focus on product development" (*parent's executive*) | Incentives and motivation |
| | "It's to my own discretion whether I would join patents or not… obviously, only if I were to invent I'll be on a patent" (*corporate spinout's inventor*)<br>"I am free to choose whether I am on there or not" (...) "Yes, we were self-motivated. But it wasn't necessarily self-triggered. Collaborations are also generated by the context in which the researchers are said 'we need to apply technologies to problems'. Everybody was motivated because they believed in that principle" (*corporate spinout's inventor and manager*)<br>"We were focused on building [product name] hardware. But when we tried to sell the hardware we found our customers couldn't use it because they needed software to run around hardware (...) we were forced to broaden our activities out of the operating system software to application software that used the hardware [product name] (…) the patents of course then became broader and began to incorporate the software we have to do (…) so we got a scenario of people broadening and becoming interdisciplinary. Definitely that happened in the [spun-out R&D unit]" (*inventor of a spun-out unit*) | Collaboration and strategic autonomy |
| | "That's usually born out of the desire to accommodate what the market is, telling them not out of a sort of an idea that incorporating multiple technologies will enhance the product that they started with" (*parent's executive*)<br>"In a more applied environment the focus tends to be on the problem, and you use whatever technique you need to solve that problem, and the goal becomes not pushing the state of the art but being good enough. (…) Corporate spinouts tend to be in the more applied case, so you get that effect there" (*parent's inventor*)<br>"Their [i.e., inventor's] interest has to broaden because the solutions require multiple technologies" (*executive of a spun-out unit*) | Clique-spanning knowledge recombination |
| | "[The two cliques] were complementary in the sense that the two technologies really adjust the problem and of course that led to a commercial opportunity" (*corporate spinout's inventor and manager*) | Intra-unit ties |
| | "After the spinout you are still able to find people within the previous company, and use that network" (*corporate spinout's inventor and manager*) | Inter-unit ties |
| | "[The corporate spinout] becomes sort of a platform which the inventors will grow in terms of their understanding in connection to manufacturing, marketing financial activities, things they have never seen before" (*parent's executive*) | New normative order |
| | "There is one or maybe two people who will knock at the door, and say 'hey, we have a great idea!'… and then you say what they need for their next step,… then these people will pull along the second and the third person, and then maybe you would advise saying 'hey, you should talk to person x, y, z'… they might go out there and come back to you saying 'thank you for your advice!" (*parent's executive who joined a corporate spinout*) | Executives' advices |

## Table 9. Theoretical implications from the empirical findings

| Findings | Received theory | Novel implications |
|---|---|---|
| **Question 1: What are the patterns of intra-corporate R&D collaborations before and after R&D unit reorganizations through corporate spinouts? How do these patterns differ in terms of corporate R&D employees' propensity to establish intra-corporate clique-spanning ties?** | | |
| 1. The reorganization of a R&D unit through a corporate spinout is associated with an increased connectivity of the intra-corporation co-invention network through (i) within-spinout, (ii) between parent-spinout and (iii) within-parent clique-spanning ties. | Shorter organizational distance between managers and researchers provides the researchers with promotion-based incentives (Cockburn, Henderson, and Stern, 1999), distributed responsibilities and autonomy to freely allocate time and resources (Gambardella et al., 2015).<br>Spun-out employees create new meanings through new within-unit collaborations, actions, and discussions aimed at resolving the ambiguity of organizational identity created by the spinout event (Corley and Gioia, 2004).<br>Spun-out R&D employees can unlearn the expectations of appropriate behavior imposed by the parent's organizational code and thus explore distant knowledge (Chesbrough, 2003; Cirillo et al., 2014). | Collaborations across groups are difficult to establish because of bureaucracy, lengthy procedures, and the long time horizons required for developing and bringing new products to market.<br>The spinout of a corporate R&D unit generates a shock in the entire intra-corporate R&D collaboration network that is instrumental to the evolution of its cliquish structure, which is otherwise driven by structural embeddedness.<br>The effects of R&D units reorganization through corporate spinouts extend beyond inventors directly involved with them, also including inventors who are employed in the parent firm.<br>The isolation of a R&D unit into a corporate spinout is thus associated with an increased connectivity between different groups of corporate inventors (i.e., divide to connect). |
| **Question 2: Do network constrained and specialized R&D employees contribute to the generation of clique-spanning ties? Are they associated with increased clique-spanning ties after R&D unit reorganizations through corporate spinouts?** | | |
| 2. Corporate inventors with (i) high network constraints (or low brokerage) and those with (ii) specialized knowledge background are associated with the highest increase in their likelihood of post-spinout clique-spanning tie formation. | R&D employees who occupy brokerage positions hold control over information flows, and may choose to activate distant links as a way to avoid the redundancy of information and resources that exist in tightly connected cliques (Burt, 1992; Gulati et al., 2012).<br>R&D employees who hold broad knowledge experience bear lower information asymmetry and opportunity costs in the exploitation of recombinant opportunities across different groups (Melero and Palomeras, 2015)<br>Developing clique-spanning ties involves transferring high volumes and scope of specialized knowledge. Specialized inventors hold a thorough understanding of their clique's collective and tacit knowledge. Yet specialists in particular technologies may lack intrinsic motivation to share their specialized knowledge in clique-spanning collaborations (Zhao and Anand, 2013). | R&D unit reorganization through a corporate spinout does not necessarily affect the collaboration behavior of brokers and generalist inventors.<br>The reorganization may increase the intrinsic motivation of network constrained and specialized inventors to directly participate into clique-spanning collaborations.<br>Corporate spinouts may configure shorter, more direct inter-cliques links for the transfer of complex, specialized knowledge, also providing the advantage of reducing task overload on brokerage positions for the transfer of complex, specialized knowledge within the intra-corporate R&D network. |
| **Question 3: Do corporate executives play a role in the formation of clique-spanning ties after R&D unit reorganization through corporate spinouts?** | | |
| 3. When they join the spun-out R&D unit's board, the former parent firm's executives facilitate the formation of parent-spinout (i.e., inter-unit) clique-spanning collaborations. However, they are not associated with the emergence of within-spinout (i.e., intra-unit) clique-spanning collaborations. | Parent executives hold mental maps of the corporate knowledge network, which help identify synergies across corporate units (Prahalad and Bettis, 1986; Tsai, 2000).<br>Parent executives shape the incentives of corporate inventors to get involved in boundary-spanning collaborations (Karim and Williams, 2012; Kleinbaum and Tushman, 2007). | While inventors know fairly well their direct collaborators and their immediate neighbors, they are likely to have imperfect information of the global corporate co-invention network.<br>Executives provide inventors with important information about where corporate knowledge resides and who can exploit it. However, their affiliation to spun-out R&D units' board is not associated with the emergence of within-spinout clique-spanning collaborations. |

**Figure 1. Example of a clique-spanning tie across intra-corporate cliques of inventors at the Xerox Corporation in [1998, 2002]**

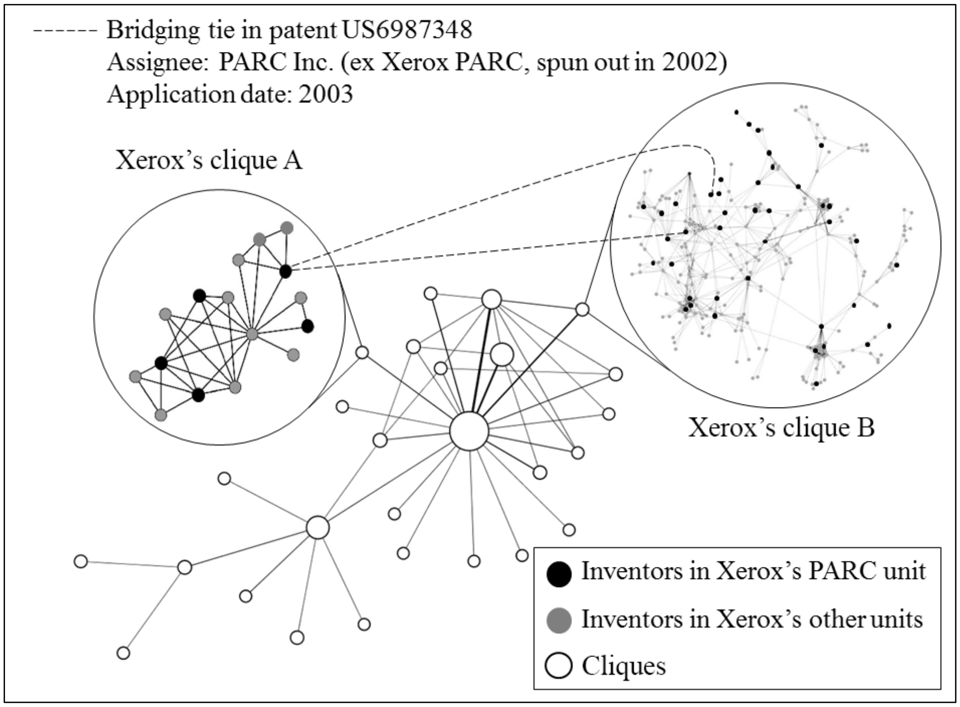
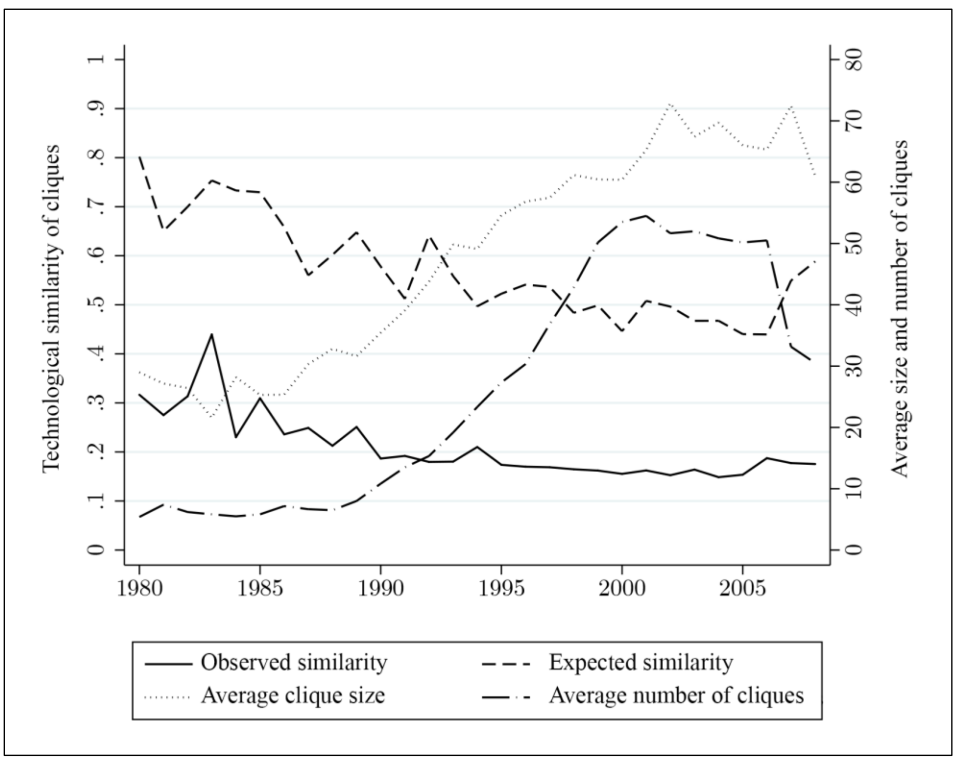



**Figure 2. Technological similarity among intra-corporate cliques of inventors (Fast-Greedy detection algorithm)**



**Appendix A. Clique detection**

This appendix illustrates the methodology we adopted to detect cliques (also called communities or clusters) of inventors within organizations. Given a collaboration network, such as the network of co-invention, cliques can be loosely defined as subsets (or clusters) of nodes such that (*i*) within each clique there are many edges among nodes (i.e. the density of within-clique links is high), but (*ii*) between cliques there are fewer edges (i.e., the density of between-clique links is lower). In other words, there must be more edges *inside* the clique than edges linking the clique with the rest of the graph (Newman, 2004). The recent advances in the science of networks have produced several methods to uncover cliques in large graphs. Fortunato (2010) provides an exhaustive survey of the broad range of concepts and approaches in this field. In general, a problem that is common to the various methods is that they are computationally very demanding, especially when the size of the network becomes large. For this reason, several clustering techniques have been elaborated with the purpose of uncovering the cliques structure of large networks in a reasonable amount of time. Broadly speaking, the existing techniques adopts the concept of *modularity*, originally proposed by Newman and Girvan (2004), as their starting point.

This notion captures the essence of the problem of detecting network cliques and its intuition can be summarized as follows. For an arbitrary partition of the network into $k$ subsets (or cliques) of nodes, one can define a $k \times k$ symmetric matrix $e$, where the element $e_{ij}$ represents the fraction of all edges in the network that link nodes in clique $i$ to nodes in clique $j$. Thus, the sum of any row (or column) of $e$, denoted by $a_i = \sum_j e_{ij}$, represents the fraction of all edges connected to nodes in clique $i$. Likewise, the sum of the elements of $e$ on the main diagonal, i.e., $\sum_i e_{ii}$, is the fraction of all edges that link nodes in the same clique. For a random network, which intuitively should not exhibit a clique structure, the expected fraction of intra-clique links is $a_i a_i$; that is, the probability that an edge begins at a node $i$ times the probability that the same edge ends at a node in $i$. The modularity index is then defined as the difference between the fraction of edges that fall within cliques and the expected value of the same quantity if the edges were randomly distributed without regard for the clique structure, namely $Q = \sum_i (e_{ii} - a_i^2)$.

For a network without a cliquish structure, the value of $Q$ is 0. Similarly, the value of $Q$ for the whole network, taken as a single clique, is 0. Values different from 0 indicate deviation from randomness. In particular, larger positive values of $Q$ suggest a significant cliquish structure. If a high value of modularity corresponds to a good partition of nodes into cliques, the partition that yields the maximum value of $Q$ should be the optimal one. Unfortunately, computing the optimal value of Q is nearly impossible, due to the extreme complexity of the problem and the time it would take. Yet, several clustering algorithms have been proposed recently, which are able to find fairly good approximations. By choosing from the various algorithms that use the notion of modularity as a global criterion to define cliques and as a key ingredient of the method, we compared four approaches: the so-called Fast-Greedy algorithm (Clauset et al., 2004), the so-called Louvain method (Blondel et al., 2008), the Infomap method (Rosvall and Bergstrom, 2008), and the Walktrap method (Pons and Latapy, 2006). For each of the four approaches and for each corporation in our sample, we computed the optimal value of $Q$. From a state in which each node was the sole member of one of *n* cliques, we repeatedly joined cliques in pairs, choosing at each step the joining that resulted in the greatest increase of $Q$ (Newman, 2006). The progress of the algorithm can be represented as a dendrogram; cuts through this dendrogram at different points of the process partition the network into more or fewer cliques. We used the cut that yielded the maximum value of $Q$ to represent the partition of a corporate co-invention network into cliques. For these calculations, we used the algorithms in the igraph library (http://igraph.org). The Fast-Greedy and the Louvain algorithms partitioned the graph into a roughly similar number of cliques and displayed the highest values of modularity for all companies in our sample and for all years examined. Results reported in the paper are based on the partitioning obtained using the Fast-Greedy algorithm.

To validate our clique detection algorithm, we dedicated the last part of our focused interviews (see section 4 and Table 8) to capturing interviewees' impressions of the graphical representations of cliques in the intra-corporate networks of their corporations. Figure A1 provides an example of such graphical representation. We showed this graph to an inventor who formerly worked in the Xerox Corporation. We asked the inventor to offer a possible explanation for why we observed two distinct groups in his ego-network. He suggested that the two cliques gathered together colleagues that not only worked on specialized technologies but also were located in specific parts of the corporate building. As he noted,

> *One group included linguistics, text speeches, and graphics. Another group was working more on artificial intelligence. And interestingly also, people on the left were on the south side of the building and people on the right were on the north side of the building.*

[Insert Figure A1 here]

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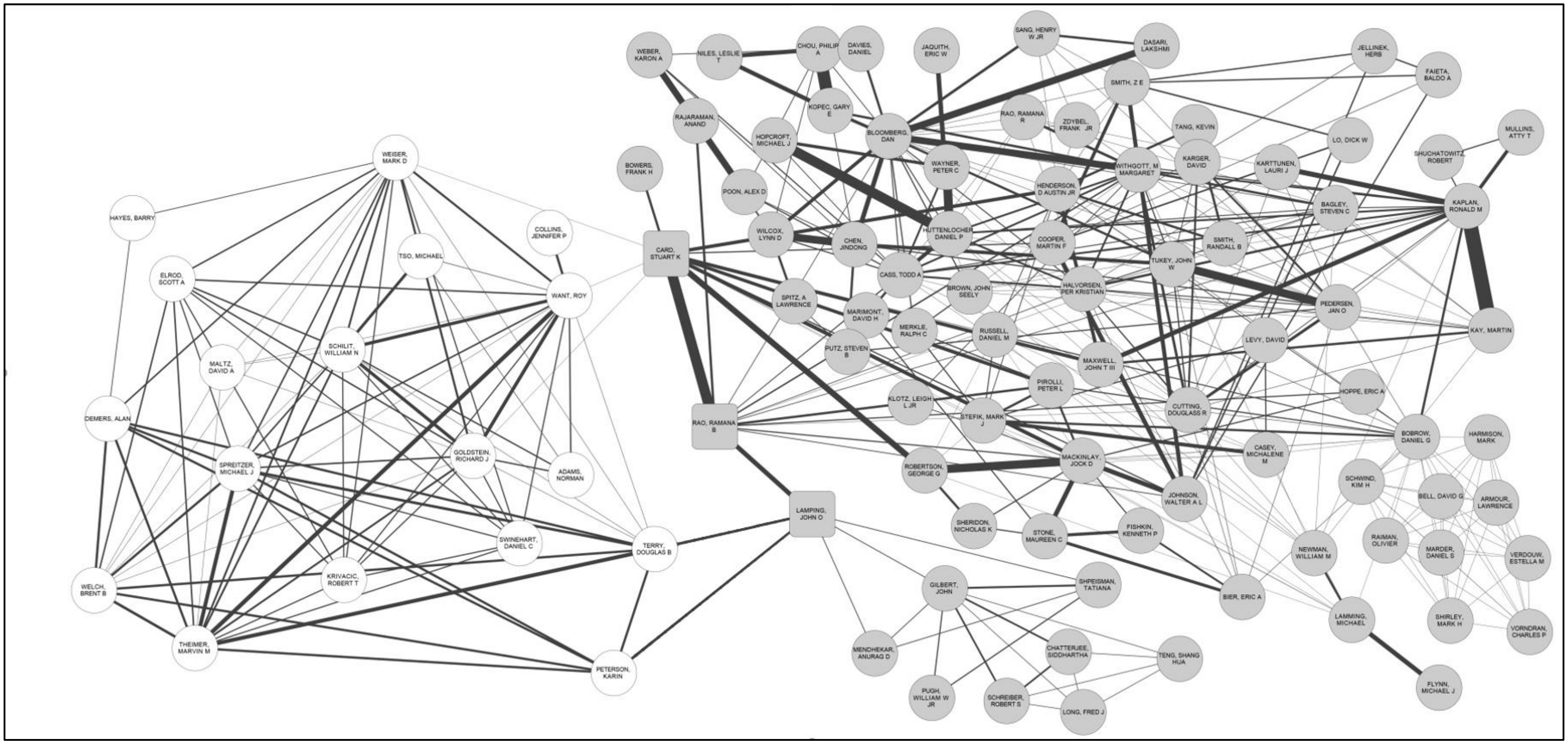
Rosvall, M., Bergstrom, C. T., 2008. Maps of random walks on complex networks reveal community structure. Proceedings of the National Academy of Sciences 105 (4), 1118–1123.

**Figure A1. Example of two intra-corporate cliques of inventors (Fast-Greedy clique detection algorithm) at the Xerox Corporation**



**Appendix B. Technological similarity among cliques**

In order to test the extent to which the pattern of knowledge specialization differs across inventors' cliques (i.e., whether knowledge is more heterogeneous between rather than within network cliques), we have proceeded in the following way. For each clique identified by our graph partitioning method, we have computed a vector representing the distribution of patents across technological fields, using the primary United States Patent Classification (USPC) code at the three-digit level assigned to the patents made by their inventors. Formally, the vector can be written as

$$\boldsymbol{C}_{it} = (C_{i1t}, C_{i2t}, C_{i3t} \dots . C_{imt}), \qquad (5)$$

where each entry denotes the share of technology *k*, for *k*=1,2…*m*, on the total patenting activity of clique *i* at time *t*. For each possible pair of cliques (*i*,*j*), we have then computed the cosine similarity index. This indicator has been widely used in the economic literature (Jaffe, 1986). It evaluates the similarity between the distribution of patents of two entities (e.g., firms, countries etc.) across technological fields by computing the cosine of the angle between the two corresponding vectors. Formally, it is defined as follows:

$$S_{ijt} = \frac{C'_{it} C_{jt}}{\sqrt{(C'_{it} C_{it})(C'_{jt} C_{jt})}} \qquad (6)$$

where $C_{it}$ and $C_{jt}$ are the vectors representing the distribution across technological fields at time *t* of patents made, respectively, by inventors in cliques *i* and *j*. The cosine similarity index ranges between zero and one. It takes value one when cliques *i* and *j* have exactly the same percentage distribution of patents across technological fields, while it takes value zero when the two cliques patent in completely different fields. After computing the value of $S_{ijt}$ for all possible pairs of cliques detected in a corporation at a given time *t*, we have computed the average value of the similarity index across all pairs.

The methodology described above produces a synthetic measure, which provides an indication of the extent to which on average the cliques of inventors existing within a corporation specialize in similar technological domains. In order to be meaningful, however, the observed average similarity measure has to be compared with some type of benchmark. To this purpose, our approach has been to ask what would be the expected value of the cosine similarity index under the assumption that inventors group into cliques for reasons that have not to do with knowledge specialization. More specifically, we kept unchanged the cliquish structure of each corporation (in terms of number, size, composition, and number of patents per clique) and we allocated patents to cliques in a random way. Then, we recomputed the cosine index for each possible pair of cliques and finally we computed the average similarity index across all pairs of cliques.

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