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Microfoundations of Firm R&D Capabilities: A Study of Inventor Networks in a Merger

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ABSTRACT Taking a cue from a recently evolving stream that calls for exploring the microfoundations of capabilities, we focus on inventor networks to examine how the activities underlying firms' R&D change in the aftermath of a merger. We view mergers as events that cause anxiety and impede inventors' abilities to process research knowledge. Employing the notion of an intra-firm inventor collaboration network, we hypothesize that in the aftermath of a merger, the impact of knowledge that is prominent and widely available in the intra-firm network will increase but that the impact of knowledge that, albeit richer, is less easily accessible, will decrease. Our empirical study of the merger of Bristol-Myers and Squibb supports our hypotheses. The findings enhance our understanding not only of mergers and acquisitions, but also of the microfoundations of a firm's R&D activities.

Keywords: intra-firm networks, mergers and acquisitions, new knowledge generation, path-altering, R&D capabilities

INTRODUCTION

Mergers are strategic actions that reflect the combination of previously independent firms, each with its own governance structure into one, commonly owned, firm (Hagedoorn and Duysters, 2002). Typically, a firm acquires or merges with another firm because the other firm has resources that complement its own (Ahuja and Katila, 2001; Haspeslagh and Jamieson, 1991). A most prominent motivation to merge is to acquire R&D capability – which is the ability of the organization to generate innovations – as merged firms gain access to the essential components of this capability, technological knowledge and inventors, of the firms with which they merge (Hagedoorn and Duysters, 2002; Haspeslagh and Jamieson, 1991; Puranam and Srikanth, 2007). Despite this motivation, empirical studies show that most of the mergers result in disruption or even

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destruction of these knowledge capabilities (Chaudhuri and Tabrizi, 1999; Paruchuri et al., 2006; Ranft and Lord, 2002), resulting in an overall reduced level of firm innovation (e.g., Hitt et al., 1990, 1991).

Explanations for why mergers or acquisitions (M&As) lead to reduced firm innovation are typically focused on firm-level strategic factors, such as capabilities' relatedness or cultural similarities (cf. Ahuja and Katila, 2001; Chatterjee, 1986; Hitt et al., 1991). In this context, scholars have looked to firms' experiences at merging with and acquiring other firms to explain differences in post-acquisition performance using a learning-based perspective. Specifically, scholars have made important strides in understanding when and which types of experiences matter (e.g., Haleblian and Finkelstein, 1999; Hayward, 2002) as well as which types of firm practices, such as the codification of acquisition-related experiences, matter (e.g., Zollo and Singh, 2004). As such, this work linking experience to learning and subsequently to performance has opened a black box of sorts in terms of understanding heterogeneous firm-level capabilities and behaviours. Very generally, these papers suggested that firms are better able to merge when managers understand the types of processes merging entails.

Indeed, recent work has argued that to better understand strategic outcomes, scholars should focus on individual-level behaviours and how these behaviours aggregate into firm-level change rather than on exogenous or firm-level sources of inter-firm heterogeneity (Abell et al., 2008; Felin and Foss, 2005, 2006; Powell and Colyvas, 2008). More specifically, these authors argued that 'while an external shock or discontinuity certainly may lead to organizations changing, how and what their responses are cannot meaningfully be ascribed to the change-inducing stimulus itself, but rather, the origins of change must lie in the choice and efforts that individuals and organizations make' (Felin and Foss, 2006, p. 282). Yet, the earlier studies on M&As have not done enough to illuminate the relationship between mergers and knowledge-building capabilities nor have they examined the internal dynamics by which such outcomes are achieved. To do so, more specific individual choices need to be examined – namely, inventors' choices within the firm.

In fact, earlier studies have shown that the development of knowledge-building capabilities hinges on the behaviour of inventors (Allen and Cohen, 1969; Nerkar and Paruchuri, 2005; Tushman, 1977). In the context of M&As, research found that acquisitions have negative effects on these knowledge workers, leading to their departures, and consequently to reducing the anticipated benefits of the M&As (Ernst and Vitt, 2000; Paruchuri et al., 2006; Ranft and Lord, 2002). In this paper, we wish to extend such work by examining the dynamics of inventor networks within the firm. We focus on the behaviours of inventors who continue to work within the new firm boundaries in response to a merger, and specifically examine how their innovation activities – their choices of which knowledge to recombine – are affected by the merger. Such changes in inventors' choices result in changes in the extent to which different knowledge is used as a building block in knowledge recombination processes and, as such, affects the overall knowledge-building capabilities of the firm (Nerkar and Paruchuri, 2005).

We begin with a review of the importance of inventors' choices regarding which knowledge to recombine in the context of a firm's R&D activities, and highlight the importance of intra-firm inventor collaboration networks within which inventors share research-related information and knowledge. We emphasize earlier research that demonstrated how the knowledge of inventors in structural positions of centrality (having many ties to other inventors) and spanning of structural holes (having ties to inventors that are not directly tied to each other) is used more in the knowledge generating activities within the firm. In the following section, we hypothesize how these dynamics are altered in the context of a merger, which we perceive as an event that affects inventors' abilities to process information, and consequently, affects the ways in which they perform R&D activities. In the next section, we empirically test these hypotheses in a longitudinal study in the context of the Bristol-Myers and Squibb merger. We find that in response to the merger, the knowledge of inventors who occupy central positions in the intra-firm network is used even more in the recombination process, but the knowledge of inventors who span structural holes is used less. In our final section, we discuss the possibility of these micro-level effects linking to firm-level outcomes, and in particular, knowledge development in the context of M&As. Specifically, we discuss how our findings contribute to the capabilities literature by offering a study that is at the micro-level rather than at the macro-concept of capability acquisition. Further, we discuss how the study contributes to the M&A literature by applying a microfoundations perspective to highlight the micro-level changes in response to a merger.

FIRM R&D CAPABILITIES: CHOICE OF KNOWLEDGE TO RECOMBINE AND THE ROLE OF INVENTOR NETWORKS

The primary function of R&D capabilities within a firm is to recombine existing knowledge in some novel ways to generate new, more advanced knowledge or innovations (Cohen and Levinthal, 1990; Fleming, 2001; Schumpeter, 1942). Obviously, the choice of knowledge that is recombined has important consequences for the evolution of R&D capabilities (Katila, 2002; Nerkar and Paruchuri, 2005; Teece et al., 1997). Specifically, evolution of capabilities is a path-dependent process, where the current positions, paths, and processes shape the evolution of capabilities (Teece et al., 1997). In the case of R&D capabilities, existing knowledge is akin to a position; different choices of knowledge to recombine in innovation activities then lead to different competencies (Nelson and Winter, 1982; Podolny and Stuart, 1995).

Within a firm, the selection of a particular inventor's knowledge for recombination in the firm's innovation activities confers her with power, prestige, and resources. So, each inventor would like her knowledge to be used by other firm inventors. However, other inventors may not be aware of the knowledge of the focal inventor and, importantly, inventors do not possess all the required knowledge for generating innovations. They have to share information amongst themselves. Sharing allows them to tap into knowledge hitherto unknown to them and bring such knowledge into the recombination activities. As such, sharing of knowledge is critical to generating innovations.

Nelson and Winter (1982) suggested that the required knowledge is unevenly distributed in the organization. In an extension of this idea, Nerkar and Paruchuri (2005) employed the notion of social networks to understand the knowledge-recombination processes. They suggested that the required knowledge is distributed in the intra-firm inventor collaboration network. That is, they proposed that the collaboration between two inventors can be considered as a tie between those inventors, and a network can be formed with inventors as nodes and all such collaborations as ties. These collaboration ties affect the ways in which innovations are generated (Katz, 1982; Tushman, 1977; Tushman and Scanlan, 1981), as different inventors know different things and they share knowledge through these collaboration ties. In this sense, the creation of new knowledge is affected by the intra-organizational relations among the firm's inventors (Kogut and Zander, 1992). Othe7r researchers have also employed this notion of an intra-firm inventor network, albeit with emphases on different aspects (cf. Allen and Cohen, 1969).

One important benefit of examining knowledge-building activities through this prism is that it allows for assessment of systematic patterns about which knowledge will be used more. That is, one can explore the use of particular knowledge in firm recombination activities by evaluating the different structural positions of its inventors. In this context, earlier research showed that the importance of a particular knowledge was determined by the position of its inventors in their firm's network. Specifically, knowledge whose inventors occupied central positions or whose inventors spanned large structural holes was used more within the firm innovation activities (Brass, 1984; Ibarra, 1993; Tushman, 1977; Tushman and Scanlan, 1981). The underlying reasons for such findings rest on two aspects of social networks: knowledge dissemination and signal interpretation.

Knowledge Dissemination

Social network theory suggests that the network positions of inventors determine the availability of their knowledge within the intra-firm network. Specifically, more central inventors have a greater number of connections to multiple other actors in their network, and hence, have wider reach in the network through several overlapping channels (Bonacich, 1987). Consequently, information about the knowledge of more central inventors is dispersed through multiple channels and is widely available in the intra-firm network compared to information about the knowledge of the less central inventors (Bonacich, 1987; Brass, 1984; Ibarra, 1993; Krackhardt, 1990). Based on this greater availability, the knowledge of central inventors is more likely to be used than the knowledge of less central inventors in the context of recombination activities.

In a different manner, information about knowledge generated by structural hole spanning inventors is available in diverse parts of the network but is dispensed through a very limited number of channels (Burt, 1992). Specifically, an inventor spans a large structural hole if he is the only bridge between unconnected groups of interconnected inventors. That is, inventors spanning structural holes form the minimal number of ties that allow them to connect the greatest number of unconnected groups of inventors. Consequently, they have non-overlapping and non-redundant ties to different unconnected groups in the network. These ties make their knowledge widely available in the network but only through unique channels (Burt, 1992). Based on this wide availability, the knowledge of structural hole spanning inventors is more likely to be used than the knowledge of inventors who span smaller or no structural holes in the context of knowledge-recombination activities (Nerkar and Paruchuri, 2005; Tushman, 1977).

Signal Interpretation

The social networks literature also suggests that the network positions of actors serve as a signal of quality, richness, status, and core-ness (Burt, 1992; Kilduff and Krackhardt, 1994; Podolny, 1993; Podolny and Stuart, 1995). Specifically, centrality is a heuristic that signals high quality (Ahuja, 2000; Kilduff and Krackhardt, 1994). Therefore, the central inventors' knowledge is perceived as knowledge of higher quality and is more likely to be used in recombination activities. What this means is that because the value of new knowledge is not known ex-ante, inventors are more likely to associate knowledge generated by more central inventors as knowledge that has a higher potential to generate new, valuable knowledge (Nerkar and Paruchuri, 2005). Additionally, central inventors are associated with other central inventors and are perceived as forming the core of the network (Bonacich, 1987; Brass, 1984). Therefore, central inventors' knowledge, compared to that of less central inventors' knowledge, represents the core of the firm's R&D activities and is more likely to be used in the recombination processes (Ibarra, 1993; Krackhardt, 1990). For this reason as well, the knowledge of central inventors will be used more than the knowledge of less central inventors in the context of knowledge-recombination activities.

Another network position which serves as a signal is that of inventors who span structural holes (Burt, 1992, 1997; Hargadon and Sutton, 1997). In particular, spanners, through their unique ties to disconnected groups, have access to unique bits of knowledge from diverse parts of the network, often knowledge that is unfamiliar to many other inventors (Allen et al., 1979; Burt, 1992). As they are not strongly associated with any specific group in the network, their knowledge is not necessarily perceived as representing the core competencies of the firm. But, as a result of this ability to bring in knowledge from diverse parts of the firm's network, the extent to which an inventor spans structural holes within a firm's knowledge network signals the richness of that inventor's knowledge (Burt, 1992; Tushman and Scanlan, 1981). Such richness also serves as a heuristic when inventors are evaluating knowledge ex-ante, and consequently, knowledge of structural hole spanning inventors will be used more relative to knowledge of inventors who span smaller or no structural holes.

HYPOTHESES DEVELOPMENT

Mergers as Anxiety and Uncertainty Evoking Events

While many firm level studies highlight mergers' benefits and positive outcomes (e.g., Ahuja and Katila, 2001; Hagedoorn and Duysters, 2002; Karim and Mitchell, 2000), almost all the studies focusing on individual responses to M&As highlighted the disruptive nature of such events (see below). Irrespective of the motivation of M&As (e.g., acquisition of knowledge capabilities), individual employees are disrupted in the process (Paruchuri et al., 2006; Ranft and Lord, 2002). That is, the process of merging two firms requires combining two independent social systems into a new identity. For example, after the 1989 merger of Bristol-Myers and Squibb, the R&D divisions of both firms were brought together into a common unit named Bristol-Myers Squibb Pharmaceutical Research Institute. Further, mergers alter organizational processes drastically and affect the day-to-day routines of most individuals in the firm. For example, Bristol-Myers Squibb Pharmaceutical Research Institute modified two important day-to-day features of research: creation of media, the biochemical materials in which experiments are conducted; and glassware sterilization. Specifically, they altered Bristol-Myers' process by centralizing the creation of media and altered Squibb's process by decentralizing the sterilization process (Leibson, 1991). As these examples show, the M&A process is complex and as such, often takes a toll on the individuals working in the merging firms – they become anxious about the extent to which the disruption will affect them personally: will it lead to their firing, demotion, promotion, a reduction in pay or benefits, or to a new culture that will be foreign and unpleasant to them, etc. (Buono and Bowditch, 1989; Isabella, 1990).

As an outcome of disruption, mergers trigger anxiety – a cognitive psychological state of general distress, uneasiness, and feelings of fear or worry – at least in the immediate aftermath of the M&A (Cartwright and Cooper, 1992; Greenhalgh, 1982; Isabella, 1990; Saunders and Thornhill, 2003). Anxiety is felt particularly around the issue of whether or not they will lose their jobs (e.g., Ashford et al., 1989; Fried et al., 1996; Fugate et al., 2002; Vaananen et al., 2004). Because inventors react to mergers as events that induce uncertainty – a psychological state of doubt about what an event signifies or portends (DiFonzo and Bordia, 1998) – they perceive them as threatening events – events that carry an anticipation of harm or loss (Folkman and Lazarus, 1985). For example, Fried et al. (1996) suggested that because mergers stifle career opportunities and can potentially impede personal growth and development, lower status, or diminish power, most individuals in the firm perceive them as threatening. These threats are likely to be most prominent when merging firms are strategically similar because employees fear that if they are working in closely related areas, several of them will be downsized or at least their relative position in the combined organization will be diminished (Larsson and Finkelstein, 1999).

At the same time, however, not all inventors may be affected equally by these disruptions (Ranft and Lord, 2002). Some inventors may actually find enhanced opportunities for personal development. For example, the most central inventors and inventors who span large structural holes, who are critical to the firm's innovation activities (Allen et al., 1979; Nerkar and Paruchuri, 2005; Tushman and Scanlan, 1981), may not feel as anxious about losing jobs as other inventors in the firm. Moreover, they may find that the newly found access to the other firm's proprietary knowledge can enhance their innovation activities. However, regardless of whether some inventors find enhanced opportunities, the overwhelming research shows that the prevalent mood in merged firms tends to be anxious.

In other words, because mergers, as disruptions, generate psychological reactions, they affect the nature of work within the firm. In our context, inventors' work is therefore affected by mergers because such situations of anxiety and uncertainty limit their cognitive abilities (Fugate et al., 2008). Specifically, their work-related information processing ability is impeded because their attention is diverted to coping with the disruptive event by continuously assessing what is at stake and which resources and options are available to deal with the situation (Folkman and Lazarus, 1985; Fugate et al., 2008; Staw et al., 1981). In other words, worrying about their personal outcomes is at the expense of processing information about their work.

Effect of a Merger in the Context of Central Inventors

We present arguments here to suggest that the positive relationship between the impact of knowledge and its inventors' centrality will be amplified in the post-merger context described above. With regard to the knowledge dissemination mechanism, when people process information under uncertainty and anxiety, they are more likely to pay attention to information that is easily available and accessible (Staw et al., 1981; Tversky and Kahneman, 1989). Within the context of intra-firm R&D activities, information about the work of an inventor that is received from multiple overlapping communication channels would be more easily available and accessible. This implies that the knowledge generated by more central inventors is more readily available and easier to access. To explain, central inventors are connected to many inventors through multiple ties (Bonacich, 1987) and, therefore, other inventors in the firm have multiple redundant communication channels linking them to the most central inventors. In fact, information about the work of central inventors, received by other inventors through their different contacts, will be overlapping and redundant. Additionally, because more central inventors stand to benefit by disseminating their knowledge widely in the network through redundant ties (Bonacich, 1987; Freeman, 1979), their knowledge is salient to other inventors. In contrast, information regarding the less central inventors' knowledge is neither diffused widely in the network nor available through multiple overlapping channels. Rather, information about such less central inventors' knowledge tends to be localized to a specific area of the network and is available through limited channels (Bonacich, 1987; Freeman, 1979). Less attention is paid to such information under uncertainty and anxiety.

The effect of the signal interpretation mechanism is amplified as well because inventors' diminished ability to process information is likely to increase their reliance on heuristics (Tversky and Kahneman, 1989). That is, because inventors will be able to devote less attention to objectively evaluating knowledge as they cope with the stress of the merger, they will rely on the signals associated with knowledge to an even greater extent. As mentioned earlier, knowledge generated by more central inventors represents the core of the firm's R&D activities (Nerkar and Paruchuri, 2005). Further, centrality is associated with high status and quality and as such, knowledge generated by people in these positions is considered to be of great quality (Ibarra, 1993; Ibarra and Andrews, 1993; Podolny, 1993). Moreover, as mentioned earlier, because more central inventors may not be as affected by the anxiety the merger triggers as less central ones, other inventors perceive these more central inventors as able to think clearly about work and also perceive such inventors' knowledge as indicative of the future trajectories the firm is likely to develop. This implies that the knowledge of more central inventors will be used in the firm's recombination activities to a greater extent in the post-merger context.

Taken together, these arguments suggest that the knowledge of more central inventors is not only available through multiple redundant channels but also is associated with quality signals that attract greater attention in response to the anxiety triggered by mergers. In contrast, the knowledge of less central inventors is available locally and through fewer channels and is also not associated with quality signals and thus tends to be ignored in this context. For these reasons, we expect the knowledge of central inventors to be used even more in the post-merger context compared to the pre-merger context. Thus,

Hypothesis 1: The positive relationship between the impact of knowledge in the firm's R&D activities and its inventors' centrality in the intra-firm network will be stronger in the post-merger context than in the pre-merger context.

Effect of a Merger in the Context of Structural Hole Spanning Inventors

In this section, we explain why inventors' decreased information processing abilities in the aftermath of a merger play out differently for the knowledge generated by inventors spanning structural holes. With regard to the knowledge dissemination mechanism, we argue that the reduced ability to process information is likely to reduce the attention that inventors in the intra-firm network pay to the knowledge generated by inventors that span large structural holes. To explain, inventors spanning large structural holes economize on their ties and collaborate with inventors from diverse groups that are not directly connected to one another; moreover, they do not link densely with any specific group (Burt, 1992). While their information will have a wider reach, this information will flow in unique, non-overlapping information channels within the network (Burt, 1992; Hargadon and Sutton, 1997). The larger the structural hole spanned, the more non-redundant their ties get. Consequently, information about their knowledge is available only through sparse, non-overlapping channels of communication. Such non-redundancies suggest that inventors need to 'work harder' to obtain this information, and therefore we argue that in the post-merger context, such information will be less likely to attract the attention of other inventors.

The difficulty in accessing information about the knowledge generated by boundary spanning inventors however outweighs the signalling-related qualities of this knowledge. Overall, the knowledge of inventors spanning large structural holes is associated with richness: spanners, through their unique ties to disconnected groups, are perceived as gathering and recombining knowledge from different unconnected groups (Allen et al., 1979; Burt, 1992; Hargadon and Sutton, 1997). As such, richness may also be interpreted as a heuristic when inventors' abilities to process information are impeded. But because innovation is primarily an act of recombination of information (Fleming, 2001; Schumpeter, 1934), the information dissemination mechanism is the more dominant effect relative to the signalling mechanism in innovation activities. That is, in the innovation activities under increased uncertainty and anxiety, repeated exposure to the same information is the primary mechanism that draws inventors' attention, and signals play a secondary role. Thus, we should see the following relationship:

Hypothesis 2: The positive relationship between the impact of knowledge in the firm's R&D activities and the extent to which its inventors span structural holes in the intra-firm network will be weaker in the post-merger context than in the pre-merger context.

DATA AND METHODS

Research Site

We focus on the 1989 merger of Bristol-Myers and Squibb (Parrott and Skule, 1989). These two firms offer fertile ground for investigating R&D processes as they invest heavily in R&D. This merger brought together the 12th and 14th ranked firms to form the 2nd ranked firm in terms of revenue in the pharmaceutical industry. These firms had large R&D departments with a strong history of patenting. Because patenting is the most important way of protecting intellectual property rights in the pharmaceutical industry and because firms tend to patent all possible innovations (Levin et al., 1987), patent data provide good documentation of the history of research activities in pharmaceutical firms.

In particular, the two firms had considerable overlap in research as both firms emphasized research in the same areas, i.e., the United States Patents and Trademarks Office (USPTO) technology classes 424 (drug, bio-affecting and body treating compositions), 435 (chemistry: molecular biology and microbiology), 514 (drug, bio-affecting and body treating compositions), and 540 (organic compounds). This overlap could affect individual inventors in three ways. First, the merger could increase opportunities for productive inventors to innovate as the merger provides access to complementary knowledge bases (Ahuja and Katila, 2001). Second, it could increase inventors' job insecurity as they awaited impending downsizing (Larsson and Finkelstein, 1999). Third, the merger could lower their relative position in the combined organization (Paruchuri et al., 2006).

Irrespective of these ensuing opportunities or insecurities, the merger process created anxiety for the majority of inventors in the immediate aftermath of the merger, as they were forced, in the context of the integration processes, to undergo changes in their identification and day-to-day processes. For example, the *Wall Street Journal* (1990) reported that Dr Haber was hired to integrate the research divisions of the merging firms, and Bristol-Myers Squibb's 1990 annual report indicates consolidation of R&D operations.[1,2] Similarly, the *Wall Street Journal* (1991) stated:

> Dr Rosenberg takes over a post in which Dr Haber over the past year has fused the research staffs of two drug companies, Bristol-Myers and Squibb, which merged two years ago.

In addition to changes to the identification processes of inventors, resulting from the changes to the organizational units demonstrated by the above quotes, day-to-day processes in both the Bristol-Myers and Squibb research units were modified and integrated, as mentioned earlier in the paper. For example,

> . . . the Squibb research and development labs centralized glassware sterilization and creation of media, the biochemical materials in which experiments are conducted. But at the Wallingford, Connecticut, facility, previously Bristol-Myers' R&D complex, researchers wash their own glassware and make their own media. Currently, Bristol-Myers Squibb's facilities services is looking into centralizing media at the Connecticut

site to allow the bulk chemical purchases while decentralizing some of the glassware sterilizing in Lawrenceville. (Leibson, 1991)

Such integration processes result in the creation of a new identity and new processes and procedures. Previous research showed that such changes generate uncertainty and anxiety (Paruchuri et al., 2006; Ranft and Lord, 2002).

We collected, from the USPTO website, information about patents assigned to the two independent firms (Bristol-Myers and Squibb) before the merger and about patents assigned to the combined firm (Bristol-Myers Squibb) after the merger. Each patent has information about the inventors who created the innovation, the application date representing the latest day when the innovation was complete, and the grant date representing the day the firm acquired legal ownership of the knowledge niche. We gathered this information about patents assigned to each of the independent firms with application dates between 1975 and 1989 and patents assigned to the combined firm from 1989 to 1992. We stopped the observation at the end of 1992 as observation beyond this period may again capture a context of organizational stability, in which inventors no longer feel threatened, and consequently, their information processing abilities no longer taxed.

In greater detail, we selected the appropriate period for studying this organizational disruption by examining news about the Bristol-Myers and Squibb merger. Going into the merger, the firm's CEO expected that merger-related cuts would affect about 10 per cent of the workforce. Furthermore, he assessed that most of these would take place in 1990 and 1991, but that a few might happen in 1992 as well (Waldholz, 1990). Further, changes related to R&D integration were ongoing even after two years, as can be seen by the quote from the 1991 *Wall Street Journal*. Earlier empirical research also supported a focus on such post-merger windows to capture the effects of anxiety and uncertainty arising from M&A events (Buono and Bowditch, 1989; Fried et al., 1996; Fugate et al., 2002; Vaananen et al., 2004). For example, Fried et al. (1996) studied an acquisition in which the integration of both firms was delayed and found that managers' perceptions of the acquisition as a negative experience likely to harm their career opportunities and deter their growth and development persisted for 16 months following the merger despite the delay in integration. Based on these prior findings and the information on the merger from the press, we decided to collect the data up to the end of 1992.

Sample, Dependent Variable, and Analytical Technique

Sample and dependent variable. Our hypotheses are about the change in the impact of the knowledge generated by different inventors in response to a merger. So, we use all the patents generated by the two firms from 1980 to the beginning of 1989 as the sample of focal patents (N = 1024).

For each patent in the sample, we identified other patents from the same firm that list the focal patent in their 'prior art' section, which identifies all the prior knowledge on which the focal innovation is based. The count of patent citations represents the impact and recognition of patents and inventors (Nerkar and Paruchuri, 2005; Podolny and Stuart, 1995).[3]

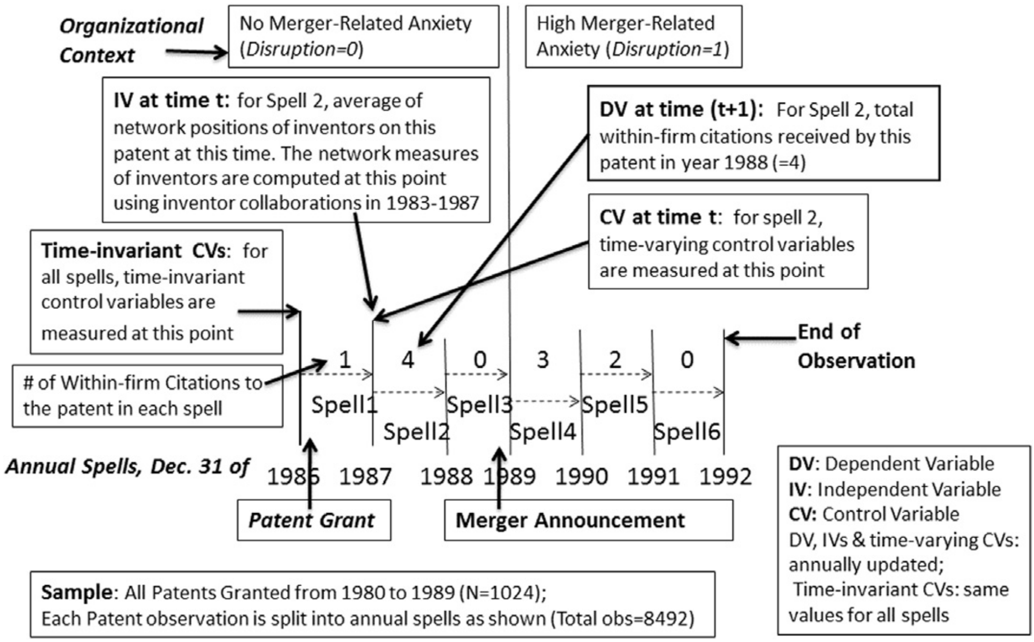

Figure 1. Example of data construction for a patent granted in 1987

Because we have a long observation period from 1980 to 1992, we split the observations into annual spells, as explained in Figure 1. That is, the annual count of a patent's citations by other patents from the same firm is our dependent variable. Because a patent could be used only after it was granted, we started the observation period for each patent when it was granted and ended the observation in 1992. As shown in Figure 1, observations of a patent that was granted in 1987 were split into six spells. We used the application date of the citing patents to create this count because the innovation was generated at the latest by that date. The use of application dates of citing patents allows us to capture any changes to the impact of different patents following the merger.

Analytical technique. To match our dataset and its characteristics (e.g., over-dispersion and dependence among annual observations of each patent), we use negative binomial distribution models (Cameron and Trivedi, 1998) and the generalized estimation equation method with robust standard errors estimated based on a patent (Liang and Zeger, 1986; White, 1980). Additionally, as shown in Figure 1, time-varying covariates are measured with one-year time lag. For example, time-varying independent and control variables are measured in 1987 for observations with the dependent variable measured in 1988.

Independent Variables

Structural positions of inventors. We hypothesized that the impact of knowledge on the firm's innovation activities depends on its inventors' network positions within the intra-firm network. Based on earlier research (Liebeskind et al., 1996; Nerkar and Paruchuri, 2005), we constructed the intra-firm inventor network using co-patenting as a tie. Specifically, because the inventors' information on each patent shows collaborations among those inventors, we used such collaboration information on the patents of each firm to construct two separate intra-firm inventor collaboration networks, one for each firm, using UCINET VI software (Borgatti et al., 2002). To get changing inventors' positions in the network, we computed each inventor's position annually and used a moving window of five years. For example, as shown in Figure 1, we used co-patenting ties on all patents in the window 1983–87 to measure intra-firm inventor network positions of inventors where dependent variables were measured in 1988 (we use four-year and six-year windows as robustness tests).

The construction of separate networks for each firm post-merger is worth noting. We were able to construct two separate networks because in the particular case of this merger, both R&D units were brought under a new administrative firm, Bristol-Myers Squibb Pharmaceutical Research Institute, in 1990 (PR Newswire, 1990), but were not operationally or geographically merged until at least the end of the observation period. That is, while the reporting structure changed, the research units in each firm maintained their original locations and work processes. Since the patents of both firms (Bristol-Myers and Squibb) were assigned under the same name, Bristol-Myers Squibb, post-merger, the identification of the intra-firm network is not straightforward. However, because the firms' R&D units were not integrated immediately after the merger (Parrott and Skule, 1989), inventors of one firm did not collaborate with inventors of the other firm and we were able to identify patents as belonging to either of the pre-merger firms based on the inventors' affiliations before the merger.[4]

From each of the five-year window networks, we measured the structural positions – centrality and spanning of structural holes – of inventors using UCINET VI (Borgatti et al., 2002) as follows.

Centrality: The advantage of using the Bonacich power as a measure of the centrality of actors is that it takes into account the centrality of others connected to the focal inventor (Bonacich, 1987; Podolny, 1993; Sorenson and Stuart, 2001). The following formula was used to calculate the centrality (Bonacich, 1987):

$$c(\alpha,\beta)=\alpha\sum_{K=1}^{\infty}\beta^{k}R^{k+1}\quad 1_i$$

where $c(\alpha, \beta)$ is a vector of centrality scores for the inventors, α is an arbitrary scaling factor, β is a weight, and **1** denotes a column-vector of ones. The magnitude and sign of the variable β determine the weight given to the centrality of inventors connected to the focal inventor in calculating the centrality of the focal inventor. This variable measures degree centrality scaled by α when β is set to zero. Inventors associated with influential inventors become more influential than inventors associated with marginal inventors when $\beta > 0$. However, when $\beta < 0$, the influence in the network of a focal inventor decreases as his/her influence increases. We set β equal to three-quarters of the reciprocal of the largest eigenvalue of X, as is the norm in the networks literature (Podolny, 1993). We converted this inventor level measure into a patent level measure by using the average of the centrality of all inventors on that patent.[5,6]

Structural holes: We employed the efficiency measure of structural holes developed by Burt (1992) that uses the ratio of non-redundant contacts to total contacts for a focal inventor as:

$$\left[\sum_j \left(1 - \sum_q p_{iq} m_{jq}\right)\right] \Big/ C_j$$

where p_{iq} is the proportion of inventor i's ties invested in connection with contact q, m_{jq} is the marginal strength of the relationship between contact j and contact q, and C_j is the total number of contacts for inventor i. Higher values on this index reflect inventors whose ego networks are rich in structural holes. If all the co-inventors of an inventor are disconnected from one another, the index takes a value of 1, indicating that none of the inventor's contacts are redundant. Again, we converted this inventor level measure into a patent level measure by using the average of the spanning structural holes measure of all inventors on that patent.[7]

Post-merger disruption indicator. The merger was our event, and the post-merger context, in which inventors had a diminished capacity to process information, was indicated with a dummy variable. To account for the one-year time lag in measuring independent variables compared to the dependent variable, we coded the indicator variable as zero for observations where the dependent variable was measured in the years before 1990 (indicating a pre-merger context) and as one for observations where the dependent variable was measured in the years from 1990 (indicating a post-merger context). This coding was used even though the merger was announced in 1989 because the onset of anxiety in response to a merger is immediate.[8] This essentially captures three-years of post-merger context, i.e., annual observations whose dependent variable was measured in 1990, 1991, and 1992.

Control Variables

There are several factors that are beyond the theoretical purview of this paper, but which nevertheless influence the observed phenomenon. We included such factors as control variables in the analyses and summarized these variables in Table I. To account for any differences that might exist between the uses of patents of two distinct networks, we also included a firm indicator variable as a control in the analyses. This variable was coded as zero for patents belonging to Bristol-Myers and one for patents belonging to Squibb. This dummy variable captures any firm-specific effects related to, for example, the technological overlap between the firms. Next, several technological characteristics influence the use of a patent (Katila, 2002; Rosenkopf and Nerkar, 2001). Because there could be differences in the rates of citations of patents belonging to different areas, we included fixed effects for each of the USPTO technology classes in which these firms have multiple patents. These fixed effects capture any perceived or real differences in the value of particular technology classes to the merged firm. Additionally, we control for the amount of innovativeness of the patent by measuring the number of claims on the patent and the complexity of the new knowledge by measuring the duration in years it took for the

Table I. Description of variables

	Variable	*Description*	*Frequency of updates*	*Time of measurement*
1	Dependent variable	Citation counts in a year	Annually updated	(t + 1)
2	Squibb indicator	Dummy indicator	Time invariant	At the time of grant (t_0)
3	Amount of innovativeness	Number of claims	Time invariant	At the time of grant (t_0)
4	Complexity	Time to patent approval	Time invariant	At the time of grant (t_0)
5	Age	Time since patent grant	Annually updated	(t)
6	No. of substitutes	No. of patents in the same class as focal patent	Annually updated	(t)
7	Citations made	No. of citations made by focal patent	Time invariant	At the time of grant (t_0)
8	Cumulative previous cites from same firm	Total # of citations received from within the firm so far	Annually updated	(t)
9	Cumulative previous cites from outside the firm	Total number of citations received from outside the firm so far	Annually updated	(t)
10	No. of inventors on a patent	No. of collaborators on the focal patent	Time invariant	At the time of grant (t_0)
11	Average tenure of inventors	Average time since first patent of inventors	Annually updated	(t)
12	Time since merger	Time since 1989 merger event	Annually updated	(t)
13	Disruption indicator	Dummy indicator	Annually updated	(t)
14	Centrality	Average centrality of inventors on focal patent	Annually updated	(t)
15	Span of structural holes	Average span of structural holes of inventors on focal patent	Annually updated	(t)

patent to be granted. We also included the age of the patent, measured as the difference between the current year and the year the patent was granted, along with its square term to capture any time dependence (Podolny and Stuart, 1995). We included the non-linear term because earlier research suggests that knowledge may be used less following a period of substantial use (Abrahamson, 1991). Additionally, we included the annually updated number of the firm's patents in the same USPTO class as the focal patent to account for the effect of substitutes on the impact of the focal patent.

As technological ties to other innovations could also influence a patent's impact (Podolny et al., 1996), we control for several such ties. Specifically, we included the number of citations made by the focal patent to other patents to capture the inputs into generating this patent. We also control for annually updated cumulative prior ties received by the focal patent from other patents categorized into cumulative prior citations from the same firm to the focal patent and cumulative prior citations from outside the firm to the focal patent.

Because there could be more than one inventor on a patent, we included the team size of the inventors by measuring the number of inventors on the patent. We also included the annually updated mean tenure of these inventors, measured as the average of the time difference between the year of the current observation and the year of the first patent by each inventor, to capture any other effects of the inventors being embedded in firm routines.

Finally, we included a measure of the time since the merger event to account for any stabilization of the merger effects over time. This variable was coded as zero for observations where the dependent variable was measured in the years before 1990 and as the difference between the current year and 1989 for observations where the dependent variable was measured in the years from 1990 onwards.

RESULTS

The descriptive statistics and simple correlations are presented in Table II. There is a very high correlation of 0.89 between the time since merger variable and the post-merger indicator variable. Consequently, we present models with the merger term alone, and present results with time since merger event as a robustness check.

In addition, we examined some descriptive variables pertaining to inventors' post-merger behaviours. We found that out of 539 inventors that were active in the five-year period before the merger, only 219 inventors produced a patent in the five-year period after the merger. While we do not have hard data on whether the other inventors were fired, left voluntarily, or became unproductive while being in the same organization, for the purpose of this study it suffices to say that uncertainty and anxiety played a role in their being unproductive.

The results of the negative binomial regression on the impact of different inventors' knowledge are presented in Table III. Model 1 presents results of the model with control variables, while Model 2 presents results with inventors' structural positions. Model 2 shows that patents whose inventors are more central have higher impact on the generation of new knowledge in the firm. However, the inventors' span of structural holes does not have any direct effect on the impact of their knowledge.

Models 3 and 4 present the results of the interaction of the post-merger indicator variable with the extent to which an inventor is central or spans structural holes, respectively. Model 5 presents both these interaction terms together in the same model; the results are plotted in Figures 2 and 3, respectively. Figures 2 and 3 plot the multiplier rate of knowledge as a function of inventors' positions in the intra-firm knowledge network.[9]

These results show that the interaction term between the post-merger indicator variable and the centrality of inventors is positive and significant, suggesting that the relationship between the multiplier rate of knowledge's impact and its inventors' centrality has a higher magnitude in response to the merger, when compared to the rate prior to the merger, supporting Hypothesis 1. The interaction term between the post-merger indicator variable and the extent to which an inventor spans structural holes is negative

Table II. Descriptive statistics and simple correlations

	Variable	*Mean*	*SD*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
1	Dependent variable	0.18	0.96	1													
2	Squibb indicator	0.64	0.48	0.07	1												
3	Amount of innovativeness	11.73	9.82	0.09	0.08	1											
4	Complexity	1.79	0.99	−0.03	−0.06	0.00	1										
5	Age	4.18	3.16	0.00	0.02	−0.03	−0.05	1									
6	No. of substitutes	55.14	59.58	0.05	0.34	0.21	−0.10	0.11	1								
7	Citations made	5.38	5.71	0.00	−0.02	0.20	0.07	−0.03	0.01	1							
8	Cumulative previous cites from same firm	0.86	4.51	0.36	0.09	0.08	−0.05	0.19	0.07	−0.02	1						
9	Cumulative previous cites from outside the firm	0.77	1.89	0.03	−0.05	0.11	−0.02	0.37	0.04	0.13	0.13	1					
10	No. of inventors on a patent	2.15	1.10	−0.04	−0.29	−0.03	0.03	−0.01	−0.10	−0.05	−0.07	0.02	1				
11	Average tenure of inventors	8.11	4.14	0.00	0.04	−0.04	0.03	0.73	0.15	−0.07	0.15	0.22	0.06	1			
12	Time since merger	0.72	1.08	−0.04	−0.01	0.02	0.03	0.52	0.17	0.01	0.06	0.22	0.01	0.41	1		
13	Disruption indicator	0.36	0.48	−0.04	−0.01	0.02	0.03	0.50	0.15	0.02	0.07	0.21	0.01	0.40	0.89	1	
14	Centrality	1.02	0.75	0.03	−0.21	−0.02	−0.03	−0.05	−0.04	−0.12	0.04	−0.03	0.58	0.20	−0.03	−0.04	1
15	Span of structural holes	0.63	0.32	0.08	0.12	0.09	−0.04	−0.22	0.11	−0.09	0.08	−0.08	−0.09	−0.02	−0.10	−0.09	0.27

Notes: All correlations with magnitude greater than |0.02| are significant at $p < 0.05$ level.

Table III. Results of negative binomial regressions on intra-firm inventors' knowledge use

	(1)	*(2)*	*(3)*	*(4)*	*(5)*
Squibb indicator	0.129	0.192	0.205	0.189	0.205
	(0.145)	(0.147)	(0.146)	(0.147)	(0.147)
Amount of innovativeness	0.035***	0.036***	0.036***	0.037***	0.036***
	(0.006)	(0.007)	(0.007)	(0.007)	(0.007)
Complexity	−0.080	−0.069	−0.064	−0.074	−0.068
	(0.069)	(0.070)	(0.070)	(0.070)	(0.070)
Age	0.454***	0.453***	0.464***	0.455***	0.467***
	(0.051)	(0.051)	(0.051)	(0.051)	(0.051)
Age^2	−0.063***	−0.061***	−0.061***	−0.061***	−0.062***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
No. of substitutes	0.004*	0.004*	0.004*	0.004**	0.004*
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Citations made	−0.006	−0.006	−0.005	−0.005	−0.005
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
Cumulative previous cites from same firm	0.029***	0.024***	0.025***	0.025***	0.025***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Cumulative previous cites from outside the firm	0.089***	0.095***	0.094***	0.092***	0.090***
	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)
No. of inventors on patent	0.190***	0.077	0.074	0.074	0.071
	(0.057)	(0.071)	(0.070)	(0.070)	(0.070)
Average tenure of inventors on patent	−0.017	−0.037	−0.045*	−0.039*	−0.046**
	(0.022)	(0.023)	(0.023)	(0.023)	(0.023)
Disruption indicator	−0.055	−0.061	−0.337**	0.564**	0.314
	(0.098)	(0.098)	(0.169)	(0.257)	(0.285)
Centrality		0.300***	0.221**	0.317***	0.228**
		(0.099)	(0.107)	(0.099)	(0.107)
Span of structural holes		0.083	0.089	0.314	0.315
		(0.184)	(0.183)	(0.208)	(0.204)
Disruption × Centrality			0.244**		0.262**
			(0.121)		(0.120)
Disruption × Span of structural holes				−0.853***	−0.916***
				(0.327)	(0.333)
Constant	−1.823***	−1.876***	−1.808***	−2.042***	−1.962***
	(0.272)	(0.301)	(0.301)	(0.311)	(0.310)
Observations	8492	8492	8492	8492	8492
No. of patents	1024	1024	1024	1024	1024

Notes: Standard errors in parentheses.
* Significant at 10%; ** significant at 5%; *** significant at 1%.
Fixed effects for different USPTO technology classes are included in the models.

and significant, suggesting that the impact of inventors' span of structural holes has lower impact in response to the merger, supporting Hypothesis 2. Figure 3 shows that the relationship between the multiplier rate of knowledge's impact and its inventor's span of structural holes is actually negative in response to the merger, while it was positive prior to the merger.

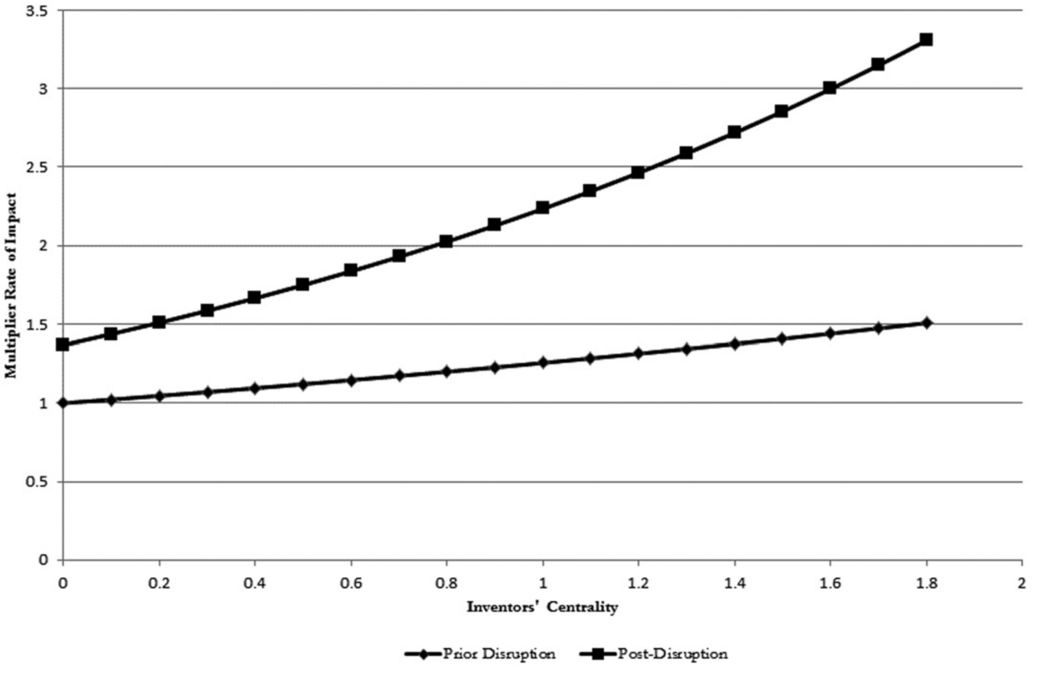

Figure 2. Impact of central inventors' knowledge on firm innovation activities

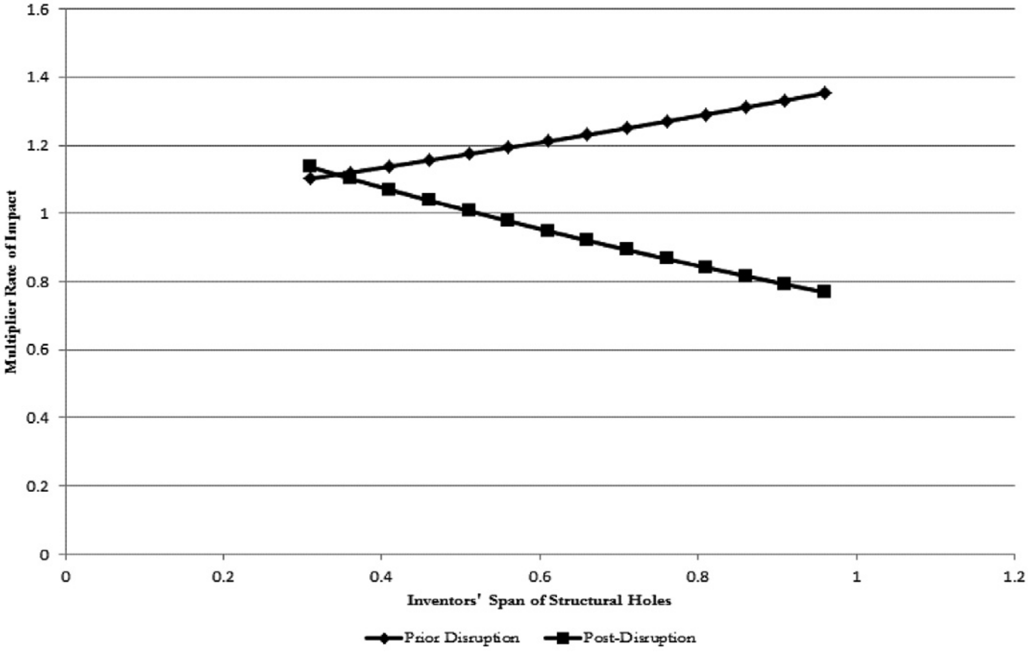

Figure 3. Impact of structural holes spanning inventors' knowledge on firm innovation activities

Robustness Checks

Because the level of anxiety could decrease as the merger becomes more distant, we present the results of the interaction of inventors' structural positions with the time since merger in Model 1 of Table IV. The results show that the impact of the knowledge of more central inventors is higher than it was prior to the merger and that it increases with time after the merger. The results in this model also show that the impact of the knowledge of inventors spanning structural holes is higher and that it decreases with time after the merger.

Because it is possible that the changes following the merger may start some time after the event, we use an alternative coding for the merger. We coded the merger as starting in 1990 instead of 1989. These results are presented in Model 2 of Table IV. The results are consistent with the results of the full model, Model 5 of Table III, supporting Hypotheses 1 and 2.

To make sure that the results are not driven by the time window in which the inventor network measures were constructed, we present two additional robustness checks. In Table IV, Model 3 presents results with inventor measures calculated in a four-year window and Model 4 presents results with inventor measures calculated in a six-year window. The results in these models show that the impact of knowledge generated by inventors whose centrality is high increases in response to the merger and the impact of the knowledge generated by inventors whose span of structural holes is high decreases in response to the merger.

DISCUSSION AND CONCLUSIONS

The findings in this paper have theoretical implications for research on microfoundations of firm capabilities as well as for research on M&As. Earlier research suggests that firms occasionally turn to specific actions, such as formation of alliances, downsizing, restructuring, and mergers or acquisitions, in an attempt to change or acquire capabilities (Helfat and Raubitschek, 2000; Karim and Mitchell, 2000; Rosenkopf and Almeida, 2003). However, most of these earlier studies focused on aggregate or 'macro' concepts at the firm- or capability-level, but did not explore how the actual change in terms of individual-level processes comes about in response to these events. Consequently, we do not yet have a good understanding of how knowledge-building capabilities are modified.

Our study sheds light on this issue by examining how one such firm-level action, a merger, changed the impact of different inventors within the firm. We found that in the post-merger context characterized by anxiety and uncertainty, the knowledge generated by more central inventors becomes more important to the firm's R&D activities but that the knowledge generated by inventors spanning larger structural holes becomes less so. As such, we are able to illuminate the changes in R&D activities following a merger at the 'micro' level.

More specifically, we theorized that mergers, due to the anxiety they generate, reduce inventors' abilities to process information and trigger particular inventor responses. Our hypotheses argued that these responses will have varying effects on the extent to which the knowledge of central inventors and that of inventors spanning structural holes would

Table IV. Robustness tests

Network measures time frame	*(1) 5-year window*	*(2) 5-year window; disruption coded 1990*	*(3) 4-year window*	*(4) 6-year window*
Squibb indicator	0.221	0.215	0.202	0.145
	(0.147)	(0.147)	(0.145)	(0.146)
Amount of innovativeness	0.037***	0.037***	0.036***	0.036***
	(0.007)	(0.007)	(0.006)	(0.006)
Complexity	−0.066	−0.069	−0.067	−0.073
	(0.069)	(0.070)	(0.069)	(0.069)
Age	0.472***	0.469***	0.465***	0.452***
	(0.051)	(0.051)	(0.051)	(0.052)
Age^2	−0.06***	−0.06***	−0.06***	−0.06***
	(0.005)	(0.005)	(0.005)	(0.005)
No. of substitutes	0.004*	0.004*	0.004*	0.004**
	(0.002)	(0.002)	(0.002)	(0.002)
Citations made	−0.005	−0.005	−0.005	−0.004
	(0.010)	(0.010)	(0.010)	(0.010)
Cumulative previous cites from same firm	0.026***	0.025***	0.026***	0.027***
	(0.005)	(0.005)	(0.005)	(0.005)
Cumulative previous cites from outside the firm	0.090***	0.091***	0.091***	0.088***
	(0.023)	(0.023)	(0.023)	(0.023)
No. of inventors on patent	0.071	0.070	0.085	0.142*
	(0.069)	(0.069)	(0.067)	(0.073)
Average tenure of inventors on patent	−0.048**	−0.046**	−0.045**	−0.039*
	(0.023)	(0.023)	(0.023)	(0.023)
Disruption indicator		0.409	0.022	0.006
		(0.310)	(0.108)	(0.107)
Centrality	0.189*	0.226**	0.217**	0.067
	(0.105)	(0.102)	(0.102)	(0.117)
Span of structural holes	0.312	0.277	0.368*	0.564***
	(0.199)	(0.194)	(0.191)	(0.219)
Disruption × Centrality		0.426***	0.288**	0.226*
		(0.129)	(0.126)	(0.120)
Disruption × Span of structural holes		−1.40***	−0.90***	−0.842**
		(0.386)	(0.311)	(0.351)
Time since disruption	0.129			
	(0.128)			
Time since disruption × Centrality	0.183***			
	(0.052)			
Time since disruption × Span of structural holes	−0.50***			
	(0.156)			
Constant	−1.94***	−1.93***	−1.62***	−1.70***
	(0.306)	(0.306)	(0.285)	(0.294)
Observations	8492	8492	8492	8492
No. of patents	1024	1024	1024	1024

Notes: Standard errors in parentheses.
* Significant at 10%; ** significant at 5%; *** significant at 1%.
Fixed effects for different USPTO technology classes are included in the models.

be used by a firm's inventors in their R&D activities. We proposed that, under such circumstances, inventors decrease information processing and reduce the number of information channels through which they seek information. In the post-merger context, these mechanisms mean that the knowledge generated by central inventors is used more in response to the merger because information about it is communicated in multiple, redundant, and overlapping channels of communication, and because such knowledge is also associated with high quality.

In contrast, the knowledge generated by inventors who span structural holes had less impact in response to the merger because information about it was transmitted in non-overlapping and sparse channels of communication. Despite the association of such knowledge with richness, flow in communication channels seems to be the primary mechanism for determining its impact. Another interesting finding is that we were not able to fully replicate the findings of Nerkar and Paruchuri (2005). We expected to see a positive relationship between inventors' span of structural holes and the impact of their knowledge in the years prior to the merger and expected that this relationship would be weakened in response to the merger. However, as shown in Model 2 of Table III, the relationship is not significant when the whole observation period is considered. Additionally, as shown in Figure 3, in response to the merger, the relationship is actually negative, that is, the negative relationship between the impact of knowledge and its inventor's span of structural holes in response to the merger may be cancelling the positive effect that existed prior to merger. In this manner, we can see how the relationship in a disruption-free context (i.e., the higher impact of structural hole spanning inventors on the knowledge-recombination processes) changed in response to the merger (i.e., the reduced impact of the same inventors).

Limitations and Future Research

The in-depth exploration of one merger is useful for generating a thorough understanding of the dynamics involved, but it raises the issue of external validity. While we examined a particular firm, based on the research cited throughout, we believe that the overall disruption and anxiety we assume in the case of this firm is representative of all mergers. Nevertheless, other research such as Haleblian and Finkelstein (1999), McDonald et al. (2008), and Puranam et al. (2006), shows that not all mergers are equal and the dynamics may vary with respect to prior experience of the firm or the board members or with respect to sizes of the merged firms. Experience is important because inventors' prior experience with M&As may also affect our results – experienced inventors may be better able to understand the types of behaviours and activities that underlie successful knowledge transfer. As such, there may be a substitution effect not captured by our data. Future research needs to explore differences in micro-processes in mergers affected by such characteristics. Next, while our research has specifically focused on short-term consequences of the merger, the long-term effect may differ. Future research will need to examine such long-term adjustments that occur in response to a merger (e.g., Briscoe and Tsai, 2011).

From the social networks perspective, even though we examine one merger context, we examine two distinct networks and a large sample of patent citations. Thus, our empirical strategy is superior to other studies that examined dynamics in only one network or used a small sample. Nonetheless, we examine dynamics in terms of the impact of knowledge on a firm's R&D activities only. Future research can extend the investigation to other aspects of network dynamics, such as mobility, collaboration, and productivity.

Another limitation arises from the use of patent data. Because firms in the pharmaceutical industry rely heavily on patents to protect their intellectual property, the selection of a merger in the pharmaceutical industry decreases the potential biases inherent in this issue compared to an examination of patents in other industries. While we followed earlier empirical studies, patent data do not capture the tacit knowledge inherent in the firm. Future research could qualitatively examine the effects of organizational disruptions on new knowledge generation processes to access such tacit knowledge to a greater extent. For example, when innovation processes are considered (Banerjee, 1998), how does the disruption alter these processes beyond altering the individual's activities? Finally, use of 'prior art' citations may be an issue because some of the citations may be inserted by the patent examiners. While the potentiality of this issue is minimal in our case as we examine citations from within the firm, future research could examine impact in other forms.

Contributions

Our paper makes contributions to two streams of literature: capabilities, and M&As. The capabilities literature has focused on firms and has examined how they can acquire or modify various capabilities (Helfat, 1994; Karim and Mitchell, 2000; Nelson and Winter, 1982; Stuart and Podolny, 1996; Teece et al., 1997), but without exploring the underlying dynamics. Our paper complements this stream of literature by focusing on the microfoundations of such changes in capabilities. Specifically, we followed the suggestion of Abell et al. (2008) and Felin and Foss (2005) that 'one must fundamentally begin with and understand the individuals that compose the whole, specifically their underlying nature, choices, abilities, propensities, heterogeneity, purposes, expectations, and motivations' (Felin and Foss, 2005, p. 441).

Our paper shows that anxiety arising from the merger and related integration processes altered inventors' choices of which knowledge they recombine to generate innovations. These choices are examined from the perspective of which knowledge is used to a greater or lesser extent after the merger. Such differential use of knowledge to recombine affects the evolution of a firm's R&D capability as well as technology (Nerkar and Paruchuri, 2005; Podolny and Stuart, 1995; Teece et al., 1997). We particularly show that the knowledge is used even more in the post-merger context if its inventors occupy a central position in the intra-firm network, but the knowledge is used less in the post-merger context if its inventors spanned structural holes in the intra-firm network. Thus, our paper shows how the same event, a merger, influences the impact of knowledge of different inventors differently and suggests the heterogeneity of the effects.

Additionally, our paper goes beyond the existing research on the role of intra-firm knowledge networks in the evolution of capabilities. To explain, Nerkar and Paruchuri (2005), for example, hypothesized that knowledge of central inventors and structural holes spanning inventors play a major role in the evolution of a firm's R&D capabilities. Our paper goes beyond this finding by showing the differences in these two types of inventors. Specifically, in the aftermath of a merger, central inventors' impact increases but structural holes spanning inventors' impact decreases. Moreover, our paper also separates the two mechanisms underlying the findings of Nerkar and Paruchuri (2005) and theorizes that differential changes in impacts arise in the merger context because the knowledge dissemination mechanism trumps the signal interpretation mechanism when inventors are anxious.

Our paper also adds to the M&A literature by offering an examination of how activities change in response to a merger. Recent reviews called for further pursuing an understanding of post-merger implementation and the integration and transfer of resources (Haleblian et al., 2009). Prior work used firm-level experience with M&As as a lens for understanding firms' abilities to transfer capabilities (Haleblian and Finkelstein, 1999; Hayward, 2002; Zollo and Singh, 2004). Such explorations shed light on ways in which firms develop different abilities to address merger events and subsequently, to reach different outcomes. This work has begun to link the complexity of integrating two discrete identities into one. Our paper advances this line of research by calling attention to more micro aspects of integration. Specifically, we explain knowledge acquisition by exploring how inventors modify their R&D activities in response to a merger.

Because M&As are so disruptive, understanding inventors' reactions is quite critical to realizing the benefits they can provide. In this context, our study also enhances extant work which examined how M&As fail to generate the anticipated level of knowledge transfer due to negative attitudes of employees (e.g., Chaudhuri and Tabrizi, 1999; Larsson and Finkelstein, 1999) or negative behaviours, such as departure (e.g., Paruchuri et al., 2006). Our results, which focus on the surviving inventors' behaviour in terms of their selection of knowledge to recombine, suggest changes in R&D activities in the aftermath of the merger. Specifically, the impact of knowledge of highly central inventors increased and that of knowledge of inventors spanning large structural holes decreased after the merger. As such, we add to this literature by showing how the application of a microfoundations perspective allows us to embark from a familiar question – how does the disruption caused by mergers affect inventors – to illuminate changes in the activities underlying the R&D capability.

ACKNOWLEDGMENTS

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NOTES

[1] The *Wall Street Journal* stated: 'the company said Dr Haber will head its three currently separate operating units: the Bristol-Myers Pharmaceutical Research and Development division, Squibb Institute for Medical research, and the Oncogen unit, which develops drugs for treating cancer. The units will be integrated more completely during this year's second quarter, the company said.'

[2] From Bristol-Myers Squibb's 1990 annual report: 'we consolidated management of our worldwide pharmaceutical research and development operations with the creation of the Bristol-Myers Squibb Pharmaceutical Research Institute. We are off to a good start on the merger integration process.'

[3] While recent research has shown that such 'prior art' also includes citations added by patent examiners (Alcacer et al., 2009), the potentiality of this issue in our empirical context is minimized because we are using within-firm citations. Citations from within the firm are much more likely to be made by the inventors themselves, as they are familiar with that knowledge.
[4] As a reminder, even in the absence of operational integration, the merger is still disruptive because the disruption is caused by the anticipation of impending changes the merger will spur.
[5] The results are consistent when we use the maximum of all inventors' measures on a patent.
[6] To test for the appropriateness of this aggregation, we calculated the intra-class correlations, ICC(1) and ICC(2), to assess the degree of agreement at the patent level. ICC(1) provides an estimate of between-unit variability which is essentially the percentage of total variance in scores that is explained by patent membership (Bliese, 2000; James, 1982). The ICC(1) value for the mean centrality measure on all patents in the sample was 0.499. Historically, ICC(1) values have ranged from 0 to 0.5 with a median of 0.12 (James, 1982). To assess the reliability of variables at the patent level, we calculated ICC(2), which indicates the reliability of the aggregated patent means (Bliese, 2000). The ICC(2) value for the mean centrality measure on all patents was 0.957. Glick (1985) recommended a minimum cut-off of 0.60 for ICC(2). Taken together, these statistics indicate that the aggregation of inventor-level data to the patent-level was warranted.
[7] We examined ICC(1) and ICC(2) for testing the appropriateness of this aggregation. The values of ICC(1), which examines the between-unit variability, for the mean span of structural holes measure on all patents in the sample was 0.290. These values are very high compared to the historical median of 0.12 (James, 1982). The values of ICC(2), which examines the reliability of aggregated means, for the mean span of structural holes measure on all patents in the sample was 0.901; all values higher than the critical cut-off of 0.60 suggested by Glick (1985). These statistics suggest that the aggregation is warranted.
[8] We also present robustness checks where we code the merger as starting in 1990, i.e., code the variable as one for observations where the dependent variable is measured in the years from 1991 onwards.
[9] The multiplier rate of impact is defined as the independent multiplicative effect of a variable on the impact of knowledge on a firm's innovation activities when all other variables are held constant. A multiplier rate greater than 1 increases the rate and a multiplier rate lesser than 1 decreases the rate.

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