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Establishing a high-technology knowledge transfer network: The practical and symbolic roles of identification

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ABSTRACT

Knowledge transfer networks (KTNs) are composed of interconnected firms, government entities, and research organizations that play a critical role in the funding, development, and dissemination of knowledge in high-technology industries. Despite the common use of KTNs in situations that require technology inputs spanning multiple firms, little research has examined the start-up of KTNs and the marketing literature has essentially ignored them. Using social network, social identity, and relevant attribution and motivation theories, the authors build a conceptual model that explains key outcomes of start-up KTNs. A preliminary empirical investigation of a UK-wide KTN start-up finds evidence that social identification with the network is a key moderating mechanism. Identification plays a practical role in creating positive knowledge-transfer benefits for firms that are central in the KTN's social network. Identification also plays a symbolic role by affecting participants' perceptions of overall KTN performance in light of knowledge-transfer benefits that they received, and as an antecedent to affective commitment to the KTN.

1. Introduction

Networks of firms, government entities, and research organizations that share knowledge play an important role in the funding, development, and dissemination of advanced technologies. Moreover, networks of interorganizational relationships spread knowledge across market participants in many industries that produce high-technology end-products (Daniel, Hempel, & Srinivasan, 2002). Because we found no agreement in the literature regarding a label for interorganizational networks focused on knowledge transfer and sharing, we will adopt the term knowledge transfer network (KTN) from practice. KTNs may be formalized, such as an industry R&D consortium (Autio, Hameri, & Vuola, 2004) or Toyota's "knowledge-sharing network" among suppliers (Dyer & Nobeoka, 2000). Alternatively, they can be emergent informal social structures ("social capital networks," Inkpen & Tsang, 2005). For example, a social network of contractual and cooperative alliances links firms in the Boston metropolitan area that are engaged in human therapeutic biotechnology, allowing knowledge to be shared and business transactions to be arranged (Owen-Smith & Powell, 2004).

As *social* networks that cross organizational boundaries, KTNs include not only firms in market channels, but also government agencies, universities, research institutes, "think-tanks," and industry trade associations. KTNs can be critical components of markets because they channel flows of information and resources between entities within a social structure (Owen-Smith & Powell, 2004). Beyond developing and disseminating basic technology knowledge, the benefits of KTNs include transferring best practices, solving specific problems, and developing skills and expertise (Wenger & Snyder, 2000). KTNs are often supported by "flagship" firms that seek to enhance local suppliers' skills to meet the flagship's specifications (Ernst & Kim, 2002) or government and trade groups that hope to improve regional or industry competitiveness (e.g., Groenewegen, 1992). Fig. 1 illustrates the stages through which high-technologies are turned into commercial products (Dutta, Narasimhan, & Rajiv, 1999; Mohr, Sengupta, & Slater, 2005; Moorman & Slotegraaf, 1999; Webster, 1992). KTN contributions to high-technology markets center on technology development and technology application (stages B and C of Fig. 1).

Although KTNs have been a focus of research across various disciplines surrounding technology management and commercialization (e.g., Daniel et al., 2002; Ernst & Kim, 2002; Mowery & Shane, 2002; Owen-Smith & Powell, 2004), two specific gaps in the literature make this topic appropriate for a special issue of *Industrial Marketing Management* focused on the marketing of high-technology products, services, and innovations. First, recognizing that "increasingly, underlying knowledge constitutes a large part of the value" of high-technology products and services, the call-for-papers solicited research on "partnering strategies, strategic alliances, and issues

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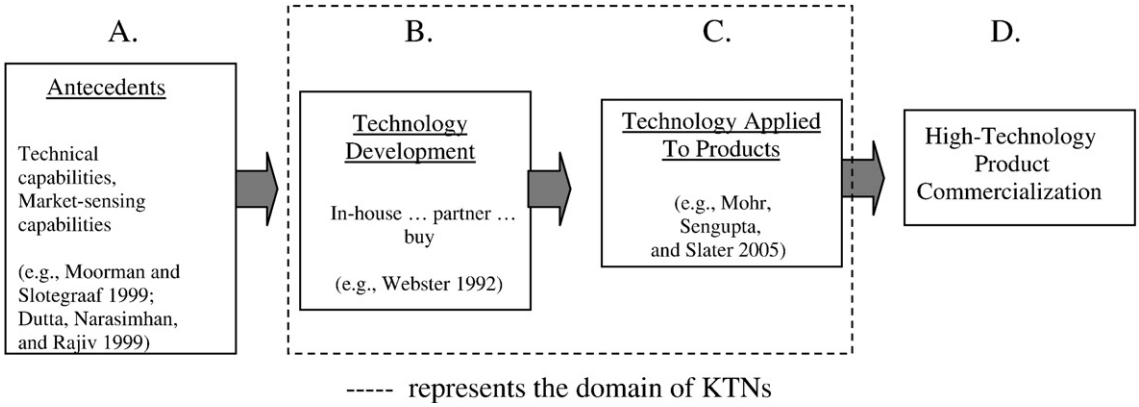


Fig. 1. High-technology product development and commercialization.

particularly pertinent to high-technology firms." Although the *concept* of social network interrelationships for research among firms is an established theme in marketing (e.g., Achrol, 1991), KTNs themselves have been virtually ignored by marketing scholars despite their use in practice and their importance to the development of products and services requiring extensive product or process technology inputs that span multiple firms (see Daniel et al., 2002 for an exception). Marketing scholars have produced substantial research on more traditional cross-firm alliances, involving two or a small number of partners that collaborate for a specific joint action (e.g., co-developing or co-marketing a product), but little research is at the social network level (see Houston et al., 2004 for a review). The IMP Group has contributed heavily to the marketing literature in the area of networks with a focus mainly on buyer–seller relationships (Dubois & Pedersen, 2002). Ritter, Wilkinson and Johnston (2004) and other scholars have broadened the scope of IMP network studies to include interactions with complementors and competitors. In contrast, KTNs extend the notion of a network to be akin to "open-sourcing" within a community of firms, where a network of organizations collaborate for the development of basic technologies and specific applications that can then be accessed by any member. Thus, because of the small amount of network-level research in marketing, much of the literature that we utilize to build our conceptualization is drawn from other disciplines.

Second, even outside of marketing, little research has addressed the *establishment* of the collaborative networks that enhance and disseminate the knowledge-base underpinning many high-technology industries. A study designed to isolate key factors that influence the outcomes of a KTN start-up effort would be valuable to this wider domain of KTN research.

The purpose of this paper is to address these two gaps through insights generated from a study of the launch of the National Composites Network (NCN; see Table 1 for an overview) in the United Kingdom. After a lengthy qualitative inquiry, we collected survey data from 62 firms involved in a KTN. Our central research objective was to isolate key factors — in a theory-based framework — that impact important KTN outcomes at both the firm level and the social network level. The remainder of this paper is developed as follows. First we provide a cross-disciplinary review of the literature that serves as a foundation for our model of KTN performance. Next, we present a conceptual framework for understanding KTN performance using the individual firm representative as the unit of analysis. Our ultimate goal is to explain actual KTN performance outcomes, but early in the life of a KTN, when our study was conducted, no objective performance measures are available. As a result, we rely on self-reported perceptions of key informants who are also the principal actors in the KTN on behalf of their firms. Third, we describe our exploratory, multi-method examination (qualitative interviews, social network data, and traditional survey data) of key factors that drive individual perceptions of KTN performance. Our study was conducted over a one-year period as a KTN was planned, organized, and launched (see Table 1). Perceptions of performance were collected at the *individual/firm* level (e.g., my firm has received knowledge-transfer benefits from involvement in the NCN) and at the *network* level (e.g., the NCN is accomplishing what it should given its level of development).

Table 1
The National Composites Network (NCN)

In mid-2004, the United Kingdom (UK) government's Department of Trade and Industry (DTI) announced that a new "knowledge transfer network," focused on high-technology composite materials[a] would be launched. The network would bring together representatives of end-product manufacturers (ranging from aircraft giants, to boat builders, automobile manufacturers, and medical product makers), suppliers of raw materials and components, as well as academic and industrial researchers, to share existing knowledge and create new technical knowledge related to composites (from basic scientific knowledge to specific processes). As one industrial researcher noted, "The [leading end-product manufacturers] are driving a move toward composite technology, but the supply chain is not in step." An executive from a large end-product maker clarified this view: "We must engage a far wider spread of [cutting edge composites abilities] throughout the supply chain, down to the [small suppliers]. Many are metal-bashing types of outfits that must educate themselves if they wish to stay in this same market."

Because composites were forecasted to gain an increasing proportion of production share, the DTI had a primary goal of protecting and creating jobs for the UK by improving capabilities throughout their country's supply chain for composite materials. Recognizing that world-class capabilities existed within individual firms and research centers in the UK, the DTI desired to create a mechanism by which disparate participants could both share and learn from others, thereby transferring knowledge and skills across the supply chain. With world-class abilities, UK suppliers would find increased demand for their composites as UK end-product manufacturers could rely more heavily on local firms for inputs, and global firms would see UK suppliers as viable sources to fulfill composite needs. Thus, end-product makers had motivation to participate in order to improve the capabilities of their supply chains, and firms across the supply chain wanted to be involved in order to acquire in-demand knowledge and skills that would help them increase sales. Thus, to great anticipation, the National Composites Network (NCN) was launched as 2004 came to a close.

In interviews with key participants surrounding the launch of the NCN, three themes emerged. First, to be seen as legitimate, the NCN had to deliver "early wins," which the interviewees defined as "real" knowledge-transfer benefits to firms across industry boundaries. Second, participants had to be engaged in and committed to the NCN; not just the large end-product firms, but even the small suppliers. One leader noted, "If people are not engaged, they feel disenfranchised and will interfere or rubbish the NCN." Third, key participants and leaders must be retained, as "defection could cause big problems."

[a] Composites are high-technology, hybrid materials created by the combination of several different basic materials (e.g., plastics, fibers, metals, ceramics), and designed to offer superior structural properties (e.g., increased strength, enhanced breakage resistance, reduced weight, better thermal properties) compared to traditional materials. Examples of composite material applications include carbon fiber used in the upper echelons of bicycle racing frames, metal matrix composites used in the landing gear of the F-16 jet aircraft, the Toyota 2ZZ-GE engine block and automotive disk brakes, and ceramic matrix composites used in extreme high-temperature environments like rocket engines.

Fourth, we present the results of our inquiry. In short, we find that identification plays a key practical role (the realization of firm-level knowledge-transfer benefits) and a key symbolic role (in evaluating the overall performance of the NCN and enhancing commitment) in the start-up of a KTN. We conclude by highlighting implications for managers and directions for future research.

2. Literature review

2.1. Knowledge sharing among firms

Knowledge transfer (KT) is defined as the act of moving knowledge from one entity to another in an optimal and reliable manner (Geraghty & Desouza, 2005). KT is a process in which one network member is affected by the experience of another through social learning (Argote & Ingram, 2000; Hansen, 1999, 2002; Inkpen & Tsang, 2005). For technology-intensive products, KT can involve the transfer of an entire range of technology knowledge, from basic science knowledge to specific processes and skills, through an "interactive process in which various specialized participants absorb, assimilate, emit and exchange knowledge inputs in a shared physical or social context" (Autio et al., 2004, p. 109; Autio & Laamanen, 1995; Amesse & Cohendet, 2001). This definition implies that KT is more than just a passive transfer. Instead, it is an interactive and dynamic process that involves effort from both the knowledge giver and receiver. A significant level of absorptive capacity is required to internalize disseminated knowledge. KT may occur through formal and informal mechanisms, although research on informal knowledge transfer is scarce (Ernst & Kim, 2002).

KT has been studied in several different but related literature streams (Hardy, Phillips, & Lawrence, 2003). In the strategy and alliance literature, knowledge transfer has been conceptualized as both a driver of and an outcome of interorganizational collaboration (Gulati, 1999; Mowery, Oxley, & Silverman, 1996). The organizational learning literature argues that collaboration not only transfers existing knowledge among organizations, but also facilitates the creation of *new* knowledge and product solutions (Aragon-Correa, Garcıa-Morales, & Cordo'n-Pozo, 2007; Gulati, 1999; Hardy et al., 2003; Powell, Koput, & Smith-Doerr, 1996). The firm-level social network literature takes a different perspective that emphasizes social capital and the position of a firm in the network as critical for KT benefits (Houston et al., 2004; Koka & Prescott, 2002). A firm's position is measured though its centrality — the degree to which it is directly and indirectly connected to other organizations and the degree to which other organizations are connected through it (Hardy et al., 2003; Tsai, 2001).

2.2. Knowledge transfer networks

In a KTN, firms gain access to valuable knowledge through social ties with other firms (Walter et al., 2007). One reason that a network can be more powerful than a dyadic relationship is that network reach carries benefits by enabling a firm to access information from diverse sources to which a firm is connected only indirectly. These indirect sources of knowledge would be inaccessible without the KTN (Koka & Prescott, 2002). As a social network, a KTN can act as a channel for information flow or become the focus of novel knowledge creation at the network level (Podolny & Page, 1998). In this paper, we focus more on the first of those effects, that is, social networks acting as channels of knowledge distribution that connect members and facilitate information flow (Fleming, King, & Juda, 2007).

Fig. 2 differentiates KTNs based on two dimensions proposed by Inkpen and Tsang (2005). The horizontal axis of Fig. 2 differentiates networks of buyer–seller relationships from networks that are more diffused (e.g., emergent networks such as the human therapeutic biotechnology in Boston, government-sponsored networks such as the NCN). Note that Inkpen and Tsang (2005) proposed a "vertical to horizontal" dimension. We have chosen to represent this dimension as ranging from buyer–seller (i.e., vertical) to diffused because many KTNs involve a wide variety of firms that are diffused across *both* the vertical and horizontal dimensions. More directly following Inkpen and Tsang, the vertical axis of Fig. 2 differentiates KTNs based on the degree to

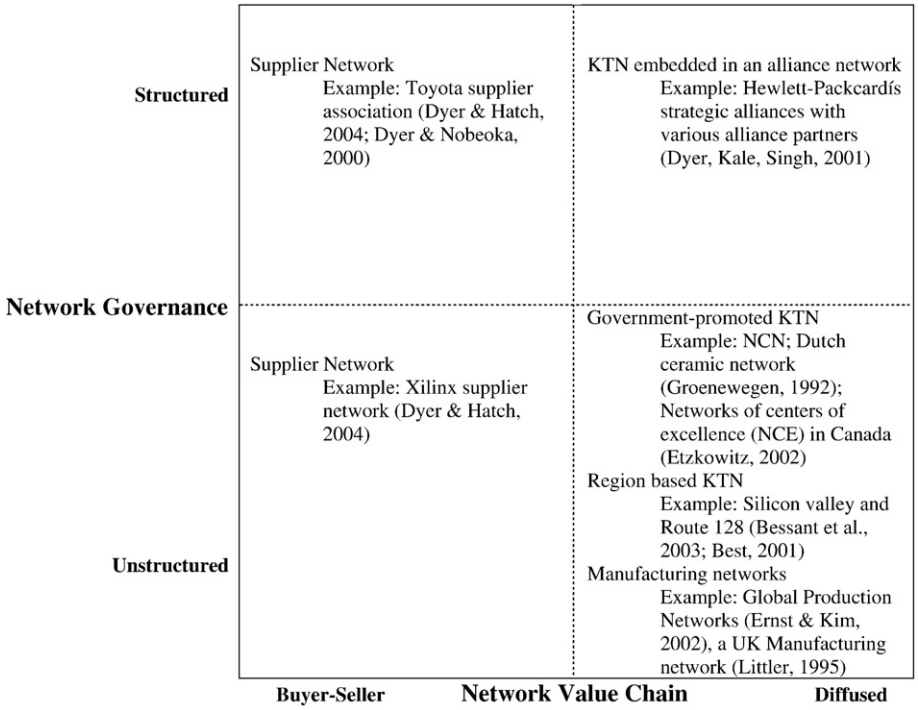


Fig. 2. Types of knowledge transfer networks (KTNs).

which network governance is formally structured. For ease of presentation, we use a two-by-two matrix, with dotted lines between any two adjacent cells to indicate that both dimensions represent continua. In Fig. 2 we provide illustrative examples of KTNs for each cell (Bessant et al., 2003, Best, 2001; Dyer, Kale, & Singh, 2001; Dyer & Hatch, 2004; Dyer & Nobeoka, 2000; Ernst & Kim, 2002; Etzkowitz, 2002; Groenewegen, 1992; Littler, Leverick, & Bruce, 1995).

Many scholars have recognized the importance of networks that we would consider to be KTNs and have linked them to competitive advantage (Baum, Calabrese, & Silverman, 2000; Dyer & Nobeoka, 2000; Inkpen & Tsang, 2005). The "knowledge-based" view of the firm sees knowledge as a key competitive asset; thus, from this perspective, a KTN is a valued source of knowledge for the firm (Mowery et al., 1996). Through participation in a KTN, an organization can access the knowledge resources and complementary capabilities of other network members, gain peer-group support, and reduce risks in R&D (Bessant, Kaplinsky, & Morris, 2003; Ernst & Kim, 2002). New knowledge from outside the firm can stimulate creativity and innovation within the firm (Bessant et al., 2003) and stimulate change and organizational improvement (Inkpen & Tsang, 2005). KTNs can also help to structure the environment and provide members with information about the environment (Groenewegen, 1992). At a more macro level, KTNs have been used by governments as a mechanism to stimulate economic growth (Bessant et al., 2003; Etzkowitz, 2002).

Consistent with theoretical arguments, empirical studies repeatedly find direct benefits for firms that participate in a KTN. These benefits include increased patent rates among biotech firms (Owen-Smith & Powell, 2004) and enhanced innovation output among chemical firms (Ahuja, 2000).

3. Conceptual framework

Our conceptual framework, illustrated in Fig. 3, focuses on three key outcomes of a high-technology KTN. *Knowledge transfer* (i.e., gaining knowledge, skills, and abilities) and the development of strong *commitment* to the network among member firms are critical firm-level outcomes for a KTN. At the network level, members should be able to assess *overall KTN performance* relative to members' investments of time and other resources. Although the conceptual framework is guided by social identity theory and related theories, the primary constructs are consistent with the themes of wholehearted participant involvement, knowledge-transfer benefits, and long-term commitment that are illustrated in the vignette in Table 1.

Interactions among member firms within a KTN are carried out by individuals who participate as agents (Bergen, Dutta, & Walker, 1992) to enact their firms' involvement in the KTN. The beliefs and behaviors of these individuals are employed on behalf of their firms, making the individual instrumental and the individual level and firm level of analysis similar in character. Thus, our framework examines individuals in the context of their roles as agents of their firms.

Given the network character of a KTN, we draw from theory in mathematical sociology (social network theory) and social psychology (social identity theory and attribution theory) to argue that centrality in the network of participants in the KTN will result in the realization of knowledge-transfer benefits from the network to the individual firm. These knowledge-transfer benefits should enhance perceptions of overall KTN performance. Within this framework, we propose that identification with the KTN — the degree to which an individual participant's self-concept includes a meaningful role for the KTN (Ashforth & Mael, 1989; Houston, Walker, Hutt, & Reingen, 2001) — will interact with network centrality to increase knowledge-transfer benefits, and will interact with knowledge-transfer benefits to increase perceptions of overall KTN performance. Finally, given the importance to a KTN of retaining key participants, we assess participants' affective commitment to the KTN. We believe that knowledge-transfer benefits, perceptions of overall network performance, and identification will relate positively to commitment.

3.1. Why social theories?

KTNs are fundamentally *social* networks comprised of interrelations among individuals who are members of distinct groups or organizations. Thus, the participation of members from different industries and organizations in KTN activities is influenced not only by rational business considerations (i.e., expected costs and financial benefits), but also by the dynamics of social forces such as expected social rewards and sanctions (McQuiston & Dickson, 1991; Ronchetto, Hutt, & Reingen, 1989). Social identity theory posits that individuals' self-concepts are defined through connections with social groups (Tajfel & Turner, 1979), including higher-order (somewhat abstract) groups (Ashforth & Johnson, 2001). Ashforth and Mael (1989) build the case that such social identity phenomena are ubiquitous in organizational and interorganizational contexts (see also Fisher et al., 1997). Identification has been demonstrated to direct managerial attention, shape managerial beliefs and interpretations, create perceptions of in-groups and out-groups (i.e., "us" versus "them"), and influence social (intergroup) behavior (e.g., Bergami & Bagozzi, 2000; Houston et al., 2001). Social identification results in perceptual biases that favor members of the in-group, and cast members of the out-group in a negative light (Hinkle & Brown, 1990; Tajfel & Turner, 1979). Thus, strong identification with a KTN has the potential to modify behavior related to the KTN and to influence perceptions of the KTN.

The social contours of a context also impact the attributional processes of individuals (cf. Fiske & Taylor, 1991). Human beings have an innate propensity to explain, or attribute causality for, important events that is driven by the desire to predict the future and control

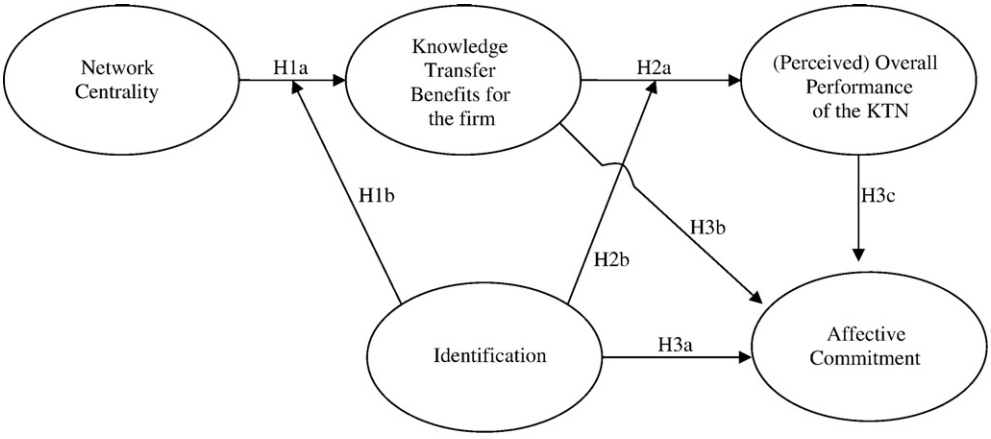


Fig. 3. Conceptual model: the critical roles of identification.

events (Heider, 1958). When they interpret the behavior of others, individuals tend to make dispositional attributions and assume that the behaviors on which they are focused reveal the "true character" of the actor (Jones & Davis, 1965). In this attribution process, people often ignore situational factors that may have caused the behavior (Gilbert, Jones, & Pelham, 1987). Jones and McGillis (1976) find that perceptions of dispositional qualities can be strongly influenced by the actor's social category membership (cf.., "She's a Southerner so of course she'll be polite," Fiske & Taylor, 1991, p. 31; see also Weisz & Jones, 1993). When category membership is linked with in-group and out-group perceptions, it is likely that positive dispositional attributions will be made for in-group members and negative dispositional traits will be attributed to out-group members (Dutton, Dukerich, & Harquail, 1994; Tajfel & Turner, 1979). Thus, attributions should differ based on whether a KTN is viewed as an in-group or an out-group.

Finally, a social network perspective suggests that network connections are required for the flow of knowledge among separate members or groups (Houston et al., 2004). A variety of socio-cognitive studies relate patterns of network involvement with the evolution of beliefs and behaviors, both in business (e.g., Dunn & Ginsberg, 1986; Frankwick, Ward, Hutt, & Reingen, 1994; Walker, 1985) and in non-commercial contexts (e.g., Carley, 1986; Ward & Reingen, 1990). Thus, members that are central in a KTN will have many opportunities to learn through their extensive exposure to the skills and abilities of fellow members (Walter, Lechner, & Kellermanns, 2007). In contrast, being central to a KTN can also cause the focal firm to receive many requests for KT from the large number of firms to which it is either directly or indirectly linked. This perspective suggests that centrality in a KTN is a double-edged sword that provides both benefits based on receiving knowledge and costs driven by requests to act as a knowledge giver for a large number of recipient firms.

3.2. Network centrality and knowledge transfer

In a high-technology KTN, one key outcome sought by member firms is to receive knowledge-transfer benefits (Ernst & Kim, 2002). As we noted earlier, we expect network position to be a key determinant of KT outcomes. Knowledge is usually distributed unevenly within a network, so network position is an important aspect of social structure that can enhance a firm's ability to create new value and to achieve economic goals (Coleman,1990; Tsai, 2001). Firms at central positions in a network are more likely to gain desired strategic resources by accessing external information and knowledge. Drawing on the socio-cognitive perspectives outlined above, centrality in a KTN should result in an individual member having the opportunity to learn from more members in the KTN (Walker, 1985). Thus, we propose a straightforward hypothesis:

H1a. Network centrality relates positively to the realization of knowledge-transfer benefits.

Recall that social identification with a group alters a member's attitudes and behaviors towards that group in favorable ways (Ward & Reingen, 1990). We expect that identification will play a key moderating role in the relationship between network centrality and knowledge-transfer benefits. Specifically, given equal levels of participation (i.e., a specific level of network centrality), an individual that is higher in identification will likely invest more effort and "think, feel, and act in ways consistent with broader [KTN] goals" (Houston et al., 2001, p. 21). In contrast, because identification is associated with managerial attention, beliefs, and positive attributions (Tajfel & Turner, 1979), we expect that individuals who are less involved with a KTN will invest less effort and provide less support for the KTN's goals than other actors who have similar centrality in the network. Thus,

H1b. Identification enhances (makes more positive) the relationship between network centrality and knowledge-transfer benefits.

3.3. Knowledge transfer and KTN performance

Overall performance of a KTN, as perceived by a member, is a subjective judgment that considers current outcomes relative to performance expectations and investments of time, effort, and other resources. An instrumental viewpoint suggests that, all else being equal, representatives who believe that their firms receive higher direct benefits from participation in the KTN will perceive overall performance of the KTN to be higher. Given that receiving knowledge-transfer benefits is a key goal for participation in most KTNs (Ernst & Kim, 2002), we propose:

H2a. Knowledge-transfer benefits (firm level) relate positively to perceptions of overall KTN performance (network level).

We argue that identification will moderate the relationship between individual firm knowledge-transfer benefits and assessment of a KTN's overall performance. Identification affects beliefs (Tajfel & Turner, 1979) and attributional processes (Fiske & Taylor, 1991; Jones & McGillis, 1976) in a way that favors the in-group. Thus, we argue that in the presence of high identification with a KTN, an *individual* firm's knowledge-transfer benefits will be more strongly attributed as evidence of the *overall* performance of the KTN. Without high identification, a firm that receives knowledge-transfer benefits may be less likely to make such haloed attributions, and thus view the overall KTN in a less favorable light.

H2b. Identification enhances (makes more positive) the relationship between knowledge-transfer benefits and perceptions of overall KTN performance.

3.4. Antecedents to affective commitment

The vignette in Table 1 illustrates that continued participation by key players in a KTN was seen as critical by network members. Similarly, Daniel et al. (2002) reviewed the literature on collaborative R&D and concluded that commitment is a key performance outcome for any research alliance. Thus, our final hypotheses are focused on antecedents to affective commitment. Extant literature suggests that three of the factors in our model should serve as antecedents to affective commitment, an emotional attachment to an entity that includes feelings of belongingness (Meyer & Allen, 1997).

First, drawing on social identity theory, identification is an important antecedent to commitment. As identification with an entity becomes more central to an individual's self-concept, affective commitment to that entity is enhanced (see Bergami & Bagozzi, 2000 for a review). The extant literature makes a clear conceptual differentiation between the cognitive nature of identification and the emotional foundation of affective commitment. Furthermore, empirical evidence consistently supports the discriminant validity of the two constructs (Ashforth & Mael, 1989; Bergami & Bagozzi, 2000; Foreman & Whetten, 2002). Both theory and empirical evidence suggest that identification provides a *basis for* organizational commitment by linking the organization to the member within the member's cognitive structure (Ashforth & Mael, 1989; Bergami & Bagozzi, 2000; Foreman & Whetten, 2002). In turn, identification alters evaluative processes and makes preferences and feelings toward the organization more positive.

Second, Morgan and Hunt (1994, p. 24–25) relate perceived benefits and performance to commitment when they note that "because partners that deliver superior benefits will be highly valued, firms will commit themselves to establishing, developing, and maintaining relationships with such partners." This logic is theoretically sound, but Morgan and Hunt (1994) failed to find a statistically significant link between relational benefits and commitment. Because they measured benefits as outcomes relative to alternatives, rather than in an absolute manner, the variance of the benefit measures may

have been attenuated (see Morgan & Hunt, 1994, p. 32). Daniel et al. (2002) draw from marketing channels literature and services research to argue that both firm-level knowledge-transfer benefits and perceptions of overall network performance should lead to enhanced commitment. In short, outcomes (positive or negative) derived from participation should drive attitudes and subsequent behavioral intentions. Although Daniel and his colleagues found supportive empirical evidence for these expectations, their operationalizations were specific to the context of their study (likely required by the National Science Foundation as sponsor of the study). They measured knowledge-transfer benefits as the communication inputs that would be expected to produce such benefits. Overall performance was actually measured as satisfaction with, rather than an evaluation of, overall performance. Commitment was measured simply as retention intentions. Nevertheless, we expect that realization of tangible knowledge-transfer benefits to one's firm and perceptions of meaningful performance by the network as a whole will enhance the affective desire for continued affiliation with the network.

H3. (a) Identification, (b) knowledge-transfer benefits, and (c) perceptions of overall performance relate positively to affective commitment.

4. Methodology

4.1. Data collection

4.1.1. Exploratory phase

In August through December of 2004 we conducted depth interviews with 15 NCN participants, including members of research and technology organizations, university researchers, and firm managers. These interviews followed a set of semi-structured questions surrounding the goals for the NCN and critical issues and success factors for its implementation, but were flexible to probe opinions and issues that emerged in the discussion. The interviews were recorded and content-analyzed by two researchers to uncover key themes. Disagreements were resolved through discussion, and the interviews were re-analyzed using a common classification scheme. Individual belief statements were placed into categories, with over 90% agreement between the two raters. These data were the basis for a structured questionnaire that probed the beliefs of NCN participants. In Appendix A, we report descriptive statistics (means, ranges, standard deviations) to indicate the relative importance of various goals and issues as perceived by the respondents. While providing insights into the launch of the NCN, the interviews also suggested (a) the importance of participant involvement in NCN activities, and (b) several factors that could play a role in explaining outcomes attributable to the NCN.

4.1.2. Survey

In June of 2005, six months after the formal launch of the NCN, we initiated an on-line survey. The 183 individuals (organization representatives, one per organization) who made up the NCN membership were invited via e-mail to complete the survey. Usable responses were received from 62 (34% response rate). We deemed this response rate to be acceptable given that membership in the NCN at the time of the data collection included all firms that had attended any public NCN events. Respondents came from a variety of backgrounds including industry, academia, private research organizations, and government. No persons with a significant number of network ties reported by other respondents were among the non-respondents. The small proportions of academic respondents in the sample (12.9%) and the population (10.9%) were similar, and in follow-up analyses, the means for academics and industry participants did not differ significantly across any of the study variables (p-values for comparisons ranged from .45 to .94).

The survey consisted of four parts. First, respondents reported their beliefs regarding the NCN. Using a seven-point scale, where either 1 = critical, and 7 = not important, or 1 = strongly agree, and 7 = strongly disagree, respondents rated their belief in statements regarding the goals and main tasks of the NCN, the usefulness of various success metrics, and critical issues and next steps for the NCN.

Note that the key informants for the firms involved in the NCN served as both reporters of the firm's activities (as in Heide & John, 1988) *and* as agents of the firm through whom most involvement in the NCN was enacted (Bergen et al., 1992). Thus, the beliefs of the key informants are *fundamental* to explaining their firms' subsequent behaviors relating to the NCN. In this context, the individual and the firm levels of assessment are virtually identical. The study centers on individuals (key informants), but in the context of the special role they played as both reporters and principle actors on behalf of their firms.

Second, the respondents reviewed a roster of the 183 individuals who were identified as members of the NCN and rated their frequency of interaction with each individual on a seven-point scale. Given two considerations, that the NCN was merely six months old and that individuals in a cross-firm network that spans several industries are likely to interact less frequently than individuals in an intra-firm network, we operationalized frequency as 1 = every few months, 3 = every few weeks, and 7 = daily. Thus, even a fairly low score might indicate the presence of a tie with reasonable strength (Bond et al., 2004; Houston et al., 2004). Network ties represent social interactions among members and are the channels for knowledge exchange (Inkpen & Tsang, 2005). Higher frequency signals stronger ties.

Third, respondents completed a series of items related to the theoretical constructs represented in our conceptual framework. Identification was measured with three items (α=.94) adapted from Mael and Ashforth (1992). Affective commitment was assessed with three items (α=.86) from a well-established scale (Allen & Meyer, 1990). We adapted five items from Spann, Adams and Souder (1995) to measure firm-level knowledge-transfer benefits (α=.97). Given the problems in measuring relational benefits noted in Morgan and Hunt (1994, p. 32), we chose items that represented the absolute level of knowledge-transfer benefits received rather than a relative level compared to an alternative. We measured overall performance with a new, four-item scale developed for this study to assess performance of the NCN relative to its youth and current level of investments (α=.93). Because externally-observable outcomes are typically not available early in the formation of a KTN or an alliance, we chose a perceptual measure as appropriate to exploratory research and as a potentially useful guide for future research. All measurement scales are found in Appendix B and a correlation matrix with means and standard deviations is provided in Table 2. The survey concluded by asking each respondent's industry (academic/education, aerospace, auto sport, automotive, construction, marine, medical, off-road, or wind energy).

4.2. Analyses

We used UCINET, version 6.150 to calculate network centrality scores from the individual self-report data on frequency of interactions

Table 2
Correlations, means, and standard deviations

	1	2	3	4	5
1. Network centrality					
2. Identification	.157				
3. Knowledge transfer	.116	.557**			
4. Overall performance	.123	.532**	.544**		
5. Affective commitment	.093	.588**	.510**	.592**	
Mean	2.09	3.10	2.96	3.42	3.38
SD	3.48	1.72	1.82	1.32	1.51

** Significant at $p<.01$.

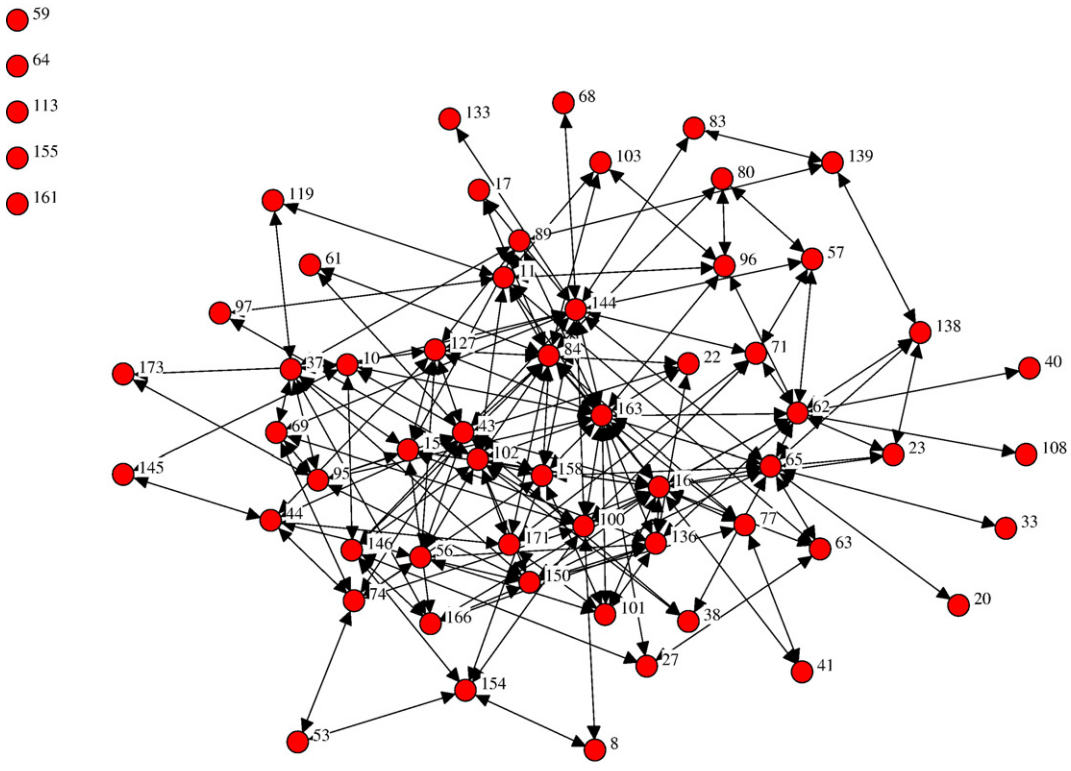
(Borgatti, Everett, & Freeman, 2002). Respondent by frequency data were combined to create a 62-by-62 matrix. Network centrality for each participant was operationalized as that individual's betweenness score, which represents the degree to which the individual can broker relationships among all other participants (Freeman, 1979). In short, betweenness captures the extent to which one individual is on the shortest network pathway between other pairs of individuals (see Appendix C for calculations). High betweenness centrality makes a network member an obligatory passage point for the information flowing through a network structure. Recall that in the NCN an individual is the key network participant on behalf of each member firm; therefore, betweenness represents a firm's ability to absorb (or interrupt) information flow (Ahuja, 2000; Owen-Smith & Powell, 2004). Burt (2007) provides recent and compelling evidence from an investment banking context that betweenness centrality is an appropriate metric to capture the information flows through one individual within a social network. Because the interpretation of betweenness centrality requires a symmetric, dichotomous matrix (Borgatti et al., 2002; Freeman, 1979), the data were symmetrized and dichotomized. Given that the frequency of interaction between two respondents is identified by row *i* column *j* (*i*'s rating of the relationship with *j*) as well as row *j* column *i* (*j*'s rating of the relationship with *i*), symmetry requires that the two ratings be equivalent. Following standard practice, when a dyad has asymmetric tie strength (i.e., when the two parties rated the frequency of interaction differently), the higher score was used to create a symmetric matrix (Bond et al., 2004). Given the cross-firm nature of our sample, any interaction with a frequency score of 3 or higher was considered a network tie with meaningful strength. Therefore, to dichotomize the data, ratings of 3 or greater were assigned a "1" while ratings of 2 or less were assigned a "0." Fig. 4 illustrates the network ties among the members of the NCN. Only five out of the 62 respondents were isolates (i.e., not connected to any other network member).

Finally, to assess the relationships among constructs, we conducted a series of multiple regression analyses and included industry as a control variable. Although it would have been desirable to utilize a structural equations modeling (SEM) approach to assess all relationships simultaneously while controlling for measurement error, our small sample size would have resulted in unstable parameter estimates. This is a particular concern in multi-group comparisons to test for moderation. Instead, multiplicative terms were created for our tests of moderation in the regression analyses. The terms were mean-centered to reduce multicollinearity (Cronbach, 1987).

5. Results

5.1. Test of conceptual model

Table 3 provides the results of our three multiple regression analyses. Contrary to our expectations, network centrality was significantly *negatively* related to the realization of knowledge-transfer benefits (H1a). However, the interaction of identification with network centrality provides strong support for the hypothesis of positive moderation (H1b) (Panel A). Similarly, although knowledge-transfer benefits did not have a significant direct relationship with perceptions of overall performance (H2a), we found a positive interaction between knowledge-transfer benefits and identification as related to perceptions of overall performance (H2b) (Panel B). Finally, in explaining affective commitment, both identification (H3a) and overall performance (H3c) were significant, positive antecedents



Note: Each node represents a respondent. Each line represents a tie of strength 3 or greater. The numbers by the node are identification numbers for the respondents. Number 59, 64, 113, 155 and 161 are isolates.

Fig. 4. Network structure for the members of the NCN.

Table 3
Determinants of knowledge-transfer benefits, overall performance and affective commitment: multiple regression results

Panel A: Determinants of perceptions of knowledge-transfer benefits			
Model statistics: $F(4,51)=6.772$; $p=.004$; R square=.181			
Predictors	Beta[a]	t	Hypothesis test
Network centrality	−.868	−2.595*	H1a
NetCent×Identification	.997	3.225**	H1b
Identification[b]	.561	2.011*	
Industry[b]	−.119	−1.271	
Panel B: Determinants of perceptions of overall performance of the KTN			
Model statistics: $F(4,52)=14.129$; $p=.000$; R square=.521			
Predictors	Beta[a]	t	Hypothesis test
Knowledge-transfer	.065	.292	H2a
KnowTran×Identification	.762	2.103*	H2b
Identification[b]	−.136	−.531	
Industry[b]	.156	1.599	
Panel C: Determinants of affective commitment to the KTN			
Model statistics: $F(4,51)=35.773$; $p=.000$; R square=.737			
Predictors	Beta[a]	t	Hypothesis test
Identification	.615	5.223**	H3a
Knowledge-transfer	−.094	−.780	H3b
Overall performance	.397	3.973**	H3c
Industry[b]	.062	.831	

[a]Standardized regression coefficients; [b]Control variable.
*Significant at $p<.05$; **Significant at $p<.01$.

(Panel C). Any effect of knowledge-transfer benefits (H3b) on affective commitment was indirect, through perceptions of overall performance.

6. Discussion and implications

Although traditional dyadic alliance research centers on issues of dependency, our network findings suggest that managing participants' identification with a KTN is a key factor in driving early success. Apart from strong identification, network centrality does not result in the realization of knowledge-transfer benefits at the firm level, nor do knowledge-transfer benefits relate to perceptions of overall KTN performance. Consistent with extant literature, identification was a key antecedent to affective commitment. Thus, we found evidence that identification plays a key practical role in the *creation* of firm-level benefits and enhanced commitment, and a key symbolic role in participants' *perception* of overall network performance.

6.1. Managerial implications

These findings have implications for practice. The basic economic resource of the 21st century is no longer raw material, labor, or capital, but knowledge (Drucker, 1992). Managers of high-technology firms work in a networked society in which learning and adaptive flexibility are more critical than reducing transaction costs (Achrol & Kotler, 1999). Our work suggests that the recruitment of participants for a start-up KTN should emphasize the development of identification with the initiative. Although connections with other firms in the social network provide *opportunities* for knowledge transfer to occur, we find that identification with the KTN provides the motivation to *engage fully* in those interactions and realize the potential for acquiring knowledge. These findings underscore the importance of viewing KTNs as social networks rather than merely as impersonal information access portals.

Further, to retain committed KTN members, identification's impact on affective commitment is particularly notable for managers of a KTN. Our results suggest that arms-length participation *without identification* may actually be *counter*productive. For a firm that is entering a KTN, the corresponding implication is that it is important to invest wholeheartedly into the success of the network. A firm that devotes the human time and effort to work for the success of the KTN *and* to secure a central position in the network for its representative (s) does much to ensure greater tangible knowledge-transfer benefits.

Although our findings suggest that strong identification yields positive practical and symbolic benefits, its moderating roles may suggest a boundary condition. Because identification strengthens perceptions of knowledge-transfer benefits for a given level of network centrality, extreme levels of identification could foster unrealistic perceptions. Similarly, individuals with exceptionally high identification may generate inflated evaluations of overall network performance based on perceptions of their firm's knowledge-transfer benefits. We saw no evidence of these effects at the levels of identification reported in our sample, but this possibility suggests that managers should be on guard against inflated judgments, a potentially fruitful direction for future research.

Finally, the social network structure of a KTN has direct implications for managers in participating firms. If a network were viewed as merely a portal from which firms could draw information when it was needed, it could be managed centrally. However, as *social* networks, KTNs are adaptive systems that cannot be directly managed (Ritter et al., 2004). Therefore, government sponsors and participating firms will be better served by managing their interactions than by attempting to manage the network itself. We believe that this insight is important because attempts to tightly control a KTN may dissuade participants from developing the high levels of identification and commitment that are critical to its success. If participants view a KTN as too closely controlled by a sponsoring agency or by an industry other than their own, they may not develop a sufficient degree of identification to enjoy firm-level benefits or to see the KTN as a successful organization to which they wish to commit over time.

6.2. Directions for future research

Further research is needed to explore the unexpected negative relationship we found between centrality and knowledge-transfer benefits. For example, a longitudinal study could examine whether this relationship is positive only at certain times during the life of a KTN. A view with some face validity centers on the notion that early in the formation of a KTN, firms with high centrality bear a burden to support transfer of knowledge to other, less central firms. Thus, highly-central firms have less opportunity to *receive* knowledge-transfer benefits and may find that the costs of providing "unwanted knowledge spillovers" outweigh the benefits that they do receive (Fleming et al., 2007, p. 951). This perspective is given some support by exploratory post-hoc regression analyses in which we found evidence that is suggestive of an inverted U-shaped relationship between network centrality and knowledge transfer. Interestingly, Owen-Smith and Powell (2004) found that betweenness centrality was negatively related to expected patenting during the early stages of a knowledge network in biotechnology, but positively related later in the network's life cycle. We found additional support for this perspective when we reviewed depth interviews with highly-central individuals and found cases in which highly-central firms were called upon to deliver knowledge transfer as an in-kind contribution to the establishment of the KTN. This activity necessarily made their short-term focus on delivery of knowledge rather than learning. However, such highly-central firms may enjoy other indirect benefits from participation in a KTN.

Second, organizational settings abound with opportunities for the development of identification with various groups because of salient demarcations of organizational, business unit, and functional lines

(Ashforth & Mael, 1989, Fisher, Maltz, & Jaworski, 1997; Houston et al., 2001). However, more research has focused on the consequences of identification than its antecedents (Bergami & Bagozzi, 2000). For members of a KTN, the focus is on an entity that is external to a participant's primary affiliation (i.e., their employer), and engagement in the KTN may be more or less voluntary. Voluntary involvement in a KTN might have positive intrinsic and extrinsic implications for one's self-esteem (Bhattacharya, Rao, & Glynn, 1995). However, the degree to which this positive image is counterbalanced by instrumentality considerations (e.g., participation "payoff") is unclear. Future research could explore the antecedents of identification with KTNs and yield useful insights to guide the rapid and successful development of future KTNs.

Because identification played a central role in the test of our conceptual model, we conducted a post-hoc investigation to discover whether the beliefs (see Appendix A) held by individuals who identified highly with the NCN differed from those held by individuals with lower identification. We split the respondents into high (above the median response) and low (at or below the median) identification groups, and compared the mean responses with ANOVA. In only five of 45 belief categories did differences reach even marginal significance. This post-hoc analysis indicates that, regardless of the level of identification, respondents generally agreed upon the goals, issues, and next steps for the NCN. Rather than influencing strategy beliefs, identification appears to be an activation mechanism to (a) convert opportunities, such as network centrality, into results, and (b) to alter perceptions of general outcomes in light of specific outcomes.

Finally, consistent with Morgan and Hunt (1994) and in contrast with Daniel et al. (2002), we failed to find a direct relationship between the perception of benefits and commitment. A potential explanation is that in our study and in Morgan and Hunt (1994), commitment was operationalized as affective commitment, while in Daniel et al. (2002), it was operationalized as a simple renewal intention (cf., planning to stay; Meyer and Allen, 1997). Perhaps the receiving of benefits from participating in a KTN is perceived as an extrinsic benefit that does not create an emotional attachment, but because the benefits are valuable, the receiver forms an instrumental intention to continue.

6.3. Limitations

First, although we developed a theoretical framework that we believe should apply to a range of KTNs, our empirical analyses explored only the participation of 62 firms in one KTN that spanned a wide range of industries. Because the NCN was a government-initiated entity, participation of industry members was voluntary. However, because large end-product manufacturers saw the potential value of the NCN and encouraged members of their supply chains to participate, it is not unreasonable to expect that our findings would apply to more formal industrial KTNs (Autio et al., 2004; Dyer & Nobeoka, 2000). Still, findings from a single empirical context need to be supplemented with results from other settings to provide evidence of generalizability. Second, our sample was small, reducing statistical power and precluding the use of structural equations modeling that would have enabled a simultaneous test of our entire model. However, access to high-level participants at an early phase of a KTN is rare and provided a glimpse into issues that could not be explored at a later point in time.

In conclusion, KTNs are important sources of new knowledge for innovative firms across a growing number of industries. Although our specific findings center on managing participants' identification with a start-up KTN, we argue that the role of KTNs in the development and management of high-technology products and services is a topic that is ripe for continued research. Our hope is that this paper suggests promising avenues for such work and motivates researchers to embrace this important topic.

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Appendix A. Descriptive findings of managerial beliefs

Prior research on KTNs has focused more on the objective characteristics of network members and has not captured the beliefs of members. If beliefs ultimately guide behavior, these beliefs can be important as they potentially enable or impede network progress. Table A1 provides descriptive data for the beliefs that we measured through our survey (lower numbers indicate higher importance or greater agreement). With respect to the goals (Table A1, Panel A) and main tasks (Panel B) of the NCN, the highest-rated beliefs were those related to increased competitiveness of the UK composites industry through education, training, and the linking of potential partner firms. Consistent with the extant literature on KTNs, participants primarily valued the NCN for its potential KT benefits. Turning to success measures (Panel C), participants desired to assess the degree to which the NCN could spread the adoption of composites across industries, create new jobs, and generate enhanced competitiveness for UK composites firms.

Regarding critical issues and success factors for the launch of the NCN (Panel D), the most highly-rated beliefs centered on the NCN delivering value to its members in a non-biased manner. Respondents from smaller firms and (i.e., non-aerospace) industries were concerned that the NCN would turn into a "puppet" of larger firms/industries who would capture a disproportionate share of benefits. For next steps (Panel E), participants rated the importance of quickly recruiting members and "hitting the ground running" most highly. These beliefs revealed concerns that early respondents would disengage if tangible benefits did not materialize quickly. In contrast to prior research, respondents were less concerned that the NCN have its own physical facility. Thus, future research could explore the importance of a physical structure to house the leadership of a KTN.

Appendix B. Scale items

Identification (α=.94)

When someone praises the NCN initiative, it feels like a personal compliment.

The successes of the NCN are my successes.

When someone criticizes the NCN, it feels like a personal insult.

Knowledge-transfer benefits (α=.97)

Knowledge transfers related to the NCN have helped my firm or its suppliers/customers solve technical problems.

Table A1
Descriptive findings regarding network participants' beliefs

	Mean	Std. Dev.	Range utilized
Panel A: Goals for the National Composites Network			
Increase use of and excitement for composites across firms and industry sectors that currently use at least some composite materials.	2.67	1.060	1–5
Build awareness and knowledge of composites to encourage their use in more conservative industries (i.e., that are slower to adopt new materials).	2.05	1.031	1–6
Create better opportunities and funding for university research, including linkages to companies (who both participate in the research and then leverage/sell the tech).	3.03	1.414	1–7

(continued on next page)

Table A1 (*continued*)

	Mean	Std. Dev.	Range utilized
Panel A: Goals for the National Composites Network			
Network all industry sectors that deal with composites to spread/share knowledge through cross-sector learning and interrelationships.	2.70	1.406	1–7
To create jobs for UK industry and improve the UK composites supply chain by improving companies' capabilities (create business benefits).	2.32	1.277	1–6
To leverage DTI's investments across industries.	3.31	1.587	1–7
Demonstrate that knowledge transfer networks can be built effectively.	3.68	1.607	1–7
Coordinate composites research across companies, universities, and regional trade organizations.	3.11	1.580	1–7
Improve the UK's basis (foundation and ability) to participate in the international composites community.	2.39	1.206	1–6
Panel B: Main tasks of the NCN			
Technology strategy development.	2.95	1.465	1–7
Supply chain development.	3.81	1.502	1–7
Education and training.	2.94	1.114	1–6
Dispersment of funding.	3.73	1.570	1–7
Joining up firms within and across industries to create synergies.	2.85	1.364	1–7
Research and creation of new knowledge.	3.22	1.379	1–7
Influencing standards for composite materials.	3.16	1.519	1–7
Provide government with a place to get information about composites-related industries.	3.71	1.508	1–7
Panel C: Importance/usefulness of various measures of success			
Growth in composites industry (jobs, rate, competitiveness).	2.56	1.398	1–7
A larger (double?) number of firms in UK employing composites, with greater incorporation of composites into products.	2.69	1.125	1–5
NCN is building excitement for composites because participants feel that knowledge and skill improvements are paying off in financial results.	3.54	1.272	1–7
Participants feel that their network of partners has grown.	3.65	1.332	1–7
DTI's seed investments generate significant capital for composites projects.	3.34	1.318	1–7
NCN is garnering attention that attracts international business and investments and attracts other industries.	3.11	1.307	1–7
Be able in 5 years to demonstrate progress towards self-funding of the NCN — the regional centers are viable, at least 5–6 total each bringing something unique to the marketplace.	3.33	1.287	1–7
Increase by 4× the contribution of composites to the UK GDP.	2.94	1.424	1–7
NCN encourages new industries to adopt composite materials.	2.52	1.127	1–5
Panel D: Critical issues and success factors			
Firms of all sizes and from all sectors must benefit, not just large players — build good relationships with small firms.	2.00	1.187	1–7
NCN must be seen as competent, impartial, and delivering "real" benefits.	1.74	.94	1–5
If firms and trade groups are not engaged, they will feel disenfranchised and withdraw or rubbish the NCN.	2.55	1.351	1–7
TWI must hire the right people to make NCN a success (proven composites experts; visionary leaders; quality ambassadors to the trade groups and regional organizations).	2.32	1.238	1–7
Must avoid defections of key partners and key NCN leaders.	3.37	1.346	1–7
NCN must act quickly and gain some "early wins" to generate buzz and to maintain the confidence of DTI.	2.82	1.176	1–6
Must leverage seed money to attract venture capital — additional funding to "make it happen."	3.11	1.042	1–6
There are complex financial, control, or contracting issues that cannot be foreseen but might damage the NCN's ability to work with the DTI, regional trade organizations, or other public bodies.	4.07	1.148	2–7
TWI must be seen as working in the NCN's best interest (not self interest) and avoid being seen as a "puppet" of the aerospace sector.	2.21	1.427	1–7
The role of the strategy group must be to serve in an advisory capacity rather than to set policy for the NCN.	3.35	1.728	1–7

Table A1 (*continued*)

	Mean	Std. Dev.	Range utilized
Panel E: Next steps for TWI and the NCN			
NCN must hit the ground running with visible, noteworthy events (networking, workshops) and get funds invested so that work can begin.	2.32	1.142	1–6
NCN manager must keep key funders in place and keep participants engaged (use them as a regular "sounding board") once a plan is agreed to.	2.61	1.030	1–7
TWI must set up tech transfer centers and processes (e.g., OEM visits) that are open and accessible to all industries.	2.94	1.158	1–7
Establish NCN formally and give it a physical home — its own facility.	4.08	1.730	1–7
The NCN must be led by a full time NCN employee who is a recognized composites expert.	2.73	1.369	1–7
NCN must identify and recruit participant firms, getting them on board regarding the value of the NCN, including non-TWI members.	2.32	1.170	1–7
Work with industry groups and firms of various sizes to map the terrain — existing composites capabilities that can be transferred and areas in need of development — and develop a technology "roadmap" for composites.	2.63	1.370	1–7
Let small companies start visiting large partners.	3.40	1.408	1–7
Detailed project plan for the five years.	2.82	1.499	1–7

Knowledge transfers related to the NCN are providing commercial successes (e.g., sales/licensing revenues, new customers, etc.) to my firm or its suppliers/customers.

Knowledge transfers related to the NCN have provided my firm or its suppliers/customers with productivity gains.

Knowledge transfers related to the NCN have resulted in cost savings for my firm or its suppliers/customers.

Individuals within my firm or our suppliers/customers seem satisfied with the knowledge transfers being received from the NCN.

Overall performance (α=.93)

The overall performance of the NCN is right where it should be at this stage.

Overall, the NCN is performing well.

The overall performance of the NCN is adequate relative to the amount of time, effort, and money being invested in it.

The NCN is creating or facilitating adequate knowledge transfer, given its stage of development.

Affective commitment (α=.86)

I enjoy discussing the NCN with people outside it.

The NCN has a great deal of personal meaning to me.

I feel a strong sense of belonging to the NCN.

Appendix C. Calculating betweenness centrality

Betweenness is a centrality measure of a vertex within a graph. Vertices that occur on many shortest paths between other vertices have higher betweenness than those that do not (Borgatti et al., 2002; Freeman, 1979).

For a graph $G:=(V,E)$ with n vertices, the betweenness $C_B(v)$ for vertex v is:

$$C_B(v) = \sum_{\substack{s \neq v \neq t \in V \\ s \neq t}} \frac{\sigma_{st}(v)}{\sigma_{st}}$$

where σ_{st} is the number of shortest geodesic paths from s to t, and $\sigma_{st}(v)$ is the number of shortest geodesic paths from s to t that pass through vertex v. The normalized score is calculated by dividing through by the number of pairs of vertices not including v, which is $(n-1)(n-2)/2$.

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