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ORCHESTRATING INNOVATION NETWORKS

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Innovation networks can often be viewed as loosely coupled systems of autonomous firms. We propose that hub firms orchestrate network activities to ensure the creation and extraction of value, without the benefit of hierarchical authority. Orchestration comprises knowledge mobility, innovation appropriability, and network stability. We reject the view of network members as inert entities that merely respond to inducements and constraints arising from their network ties, and we embrace the essential player-structure duality present in networks.

> Every herd of wild cattle has its leaders, its influential heads (Tarde, 1903: 4).

A staggering variety of networks dot the modern business landscape. One way to map this variety parsimoniously is to jointly consider network density and focal actor centrality (Rowley, 1997). In this note we focus on the low-density/high-centrality subset that is characteristic of many innovation networks. Although centrality is often associated with power and influence (Brass, 1984; Krackhardt, 1990; Wasserman & Faust, 1994) stemming from control over critical resources (Emerson, 1962), certain types of innovation networks represent an interesting situation in which hub firms lack the authority to issue commands and autonomous network members are not obliged to obey. Because network theory remains largely focused on structures, relations, and outcomes (Cook & Whitmeyer, 1992), it is silent on crucial process issues. How does the head cattle lead its herd, and how does a hub firm coordinate, direct, influence, and manage the other network members?

Hub firms (Jarillo, 1988) are known variously as key actors (Knoke, 1994), triggering entities (Doz, Olk, & Ring, 2000), strategic centers (Lorenzoni & Baden-Fuller, 1995), flagship firms (Rugman & D'Cruz, 2000), and network orchestrators (Hacki & Lighton, 2001). For example, Doz et al. (2000) suggest that, in addition to emergent processes (resulting from environmental change and chance events), there are *engineered* processes led by a triggering entity that are instrumental in the initiation and growth of a network. We define a hub firm as one that possesses prominence (Wasserman & Galaskiewicz, 1994) and power (Brass & Burkhardt, 1993) gained through individual attributes and a central position in the network structure, and that uses its prominence and power to perform a leadership role in pulling together the dispersed resources and capabilities of network members. We define network orchestration as the set of deliberate, purposeful actions undertaken by the hub firm as it seeks to create value (expand the pie) and extract value (gain a larger slice of the pie) from the network.

Certain types of innovation networks may be viewed as "loosely coupled coalitions" (Provan 1983: 83), where loose coupling is "a situation in which elements are responsive, but retain evidence of separateness and identity" (Weick, 1976: 3).[1] Paraphrasing Orton and Weick (1990), voluntarily formed, low-density innovation net-

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[1] As Orton and Weick (1990) describe it, if there is neither responsiveness nor distinctiveness, the system is non-coupled. If there is responsiveness but no distinctiveness, the system is tightly coupled. If there is distinctiveness but no responsiveness, the system is decoupled. And if there is both distinctiveness and responsiveness, the system is loosely coupled.

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works contain elements that are linked and preserve some degree of determinacy. This fact is captured by the word "coupled" in the phrase "loosely coupled." The fact that, with no hierarchical controls, these elements also preserve some degree of independence and indeterminacy is captured by the modifying word "loosely." The resulting image is of innovation networks as loosely coupled organizations (Freeman, 1991).

We chose to focus on innovation networks, both because they offer fertile ground for understanding the processes through which hub firms perform their "prime mover" functions in network operations and because of the growing importance of innovation toward competitive success. The network form of organization has profoundly impacted how companies innovate. Specifically, the dramatic disintegration of the value chain that has become commonplace in many high-tech industries has made it possible for different activities along the value chain to be carried out efficiently by different firms (Lorenzoni & Baden-Fuller, 1995). The pharmaceutical industry, for instance, has witnessed a marked shift toward external alliances for new product development (Whittaker & Boner, 1994). Such innovation typically involves high levels of transactional uncertainty and exchange of tacit knowledge—problems that demand strategic action from core actors to form and maintain a network and to extract value from it (Ahuja, 2000; Pisano, 1990; Powell, Koput, & Smith-Doerr, 1996). A major gap—addressed in this paper—concerns how hub firms orchestrate innovation networks.

This paper thus broaches a key, unexplored process issue in network management, with implications for researchers in network theory, strategy, knowledge management, alliances, and international business. We organize the rest of the paper as follows. First, we integrate multiple bodies of literature to develop a framework for orchestration in innovation networks. Next, we elaborate the three orchestration processes that a hub firm must perform—namely, managing knowledge mobility, innovation appropriability, and network stability. Interactions among these individual processes are discussed next, and, finally, we close with a comment on the essential duality of innovation networks and the member firms.

HUB FIRMS AND ORCHESTRATION

From the perspective of a hub firm, value must be created and extracted from the network (Kogut, 2000), and effective creation and extraction of value hinge on certain deliberate, purposeful actions. In the particular context of innovation networks, where knowledge is the chief currency and is dispersed, the first task of orchestration involves ensuring *knowledge mobility*. We define knowledge mobility as the ease with which knowledge is shared, acquired, and deployed within the network. Significant value cannot be created and network innovatory output will be minimal if the specialized knowledge of each network member stays mostly locked within its organizational boundaries. Conversely, a hub firm that can assess the value of relevant knowledge residing at different points in the network and can arrange its transfer to other points in the network where it is needed (Doz, 1996; Gulati, 1999; Hansen, 1999), and that can also learn from the partners and exploit resources that are made available through the network relationship (Gulati & Singh, 1998; Inkpen & Dinur, 1998; Kale, Singh, & Perlmutter, 2000; Khanna, Gulati, & Nohria, 1998), will successfully promote knowledge mobility.

Targeted mobility of knowledge within the network leads, it is hoped, to cutting-edge, proprietary innovations. The second task of orchestration involves managing *innovation appropriability* (Pisano, 1990; Teece, 1986, 2000). Appropriability is an environmental property that "governs an innovator's ability to capture the profits generated by an innovation" (Teece, 1986: 610). Potential for unauthorized imitation can be reduced, and appropriability strengthened, through such instruments as patents, copyrights, and trademarks (Sakakibara, 2002; Teece, 2000). Extending this environmental-level construct to the network level, we suggest that innovation may be stimulated or stifled, depending on the "appropriability regime" created by the hub firm. A hub firm must ensure that it is privy to the relevant knowledge development activities of network members within a broad, agreed upon framework, that there is no attempt to "cheat" by the partners (Mowery, Oxley, & Silverman, 1996), and that innovations are not leaked to actors who are linked to competing networks.

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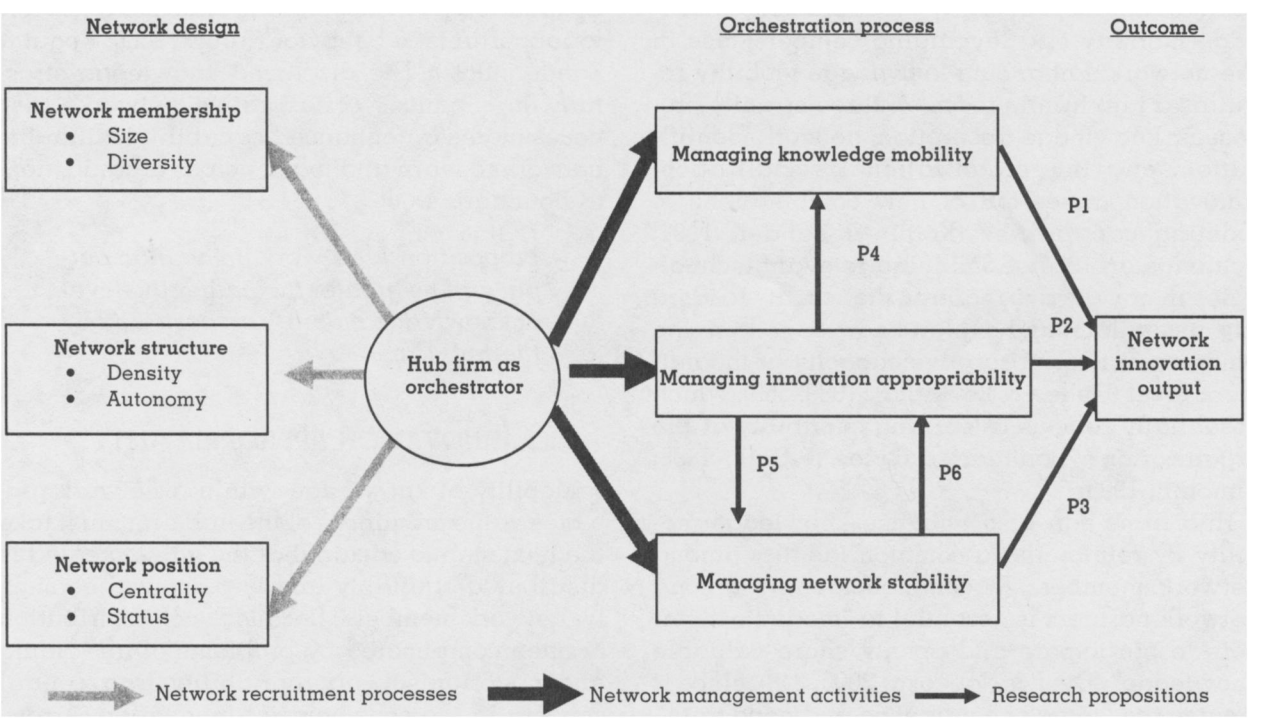
Finally, "loose coupling . . . carries connotations of impermanence, dissolvability, and tacitness" (Weick, 1976: 3); as loosely coupled systems, innovation networks may experience unstable linkages among network members. Competitive pressures among members can exacerbate the instability, whereby actors may stop collaborating with a hub firm or, worse, start collaborating with a hub firm belonging to a competing network (Gomes-Casseres, 1994; Kogut, 1988; Stuart, 2000; Uzzi, 1997). Therefore, fostering *network stability* is the third task of orchestration. We refer here to dynamic (not static) stability, which aims for a nonnegative growth rate while allowing for entry and exit of network members.

Figure 1 summarizes the above discussion. Before we discuss in greater detail each orchestration process, we make two points. First, we assume that all network players—hub, semi-peripheral, and peripheral (Gulati & Gargiulo, 1999)—will actively pursue their own self-interests. No member is inert, responding passively to the hub firm's initiatives. Indeed, it is in this context of absence of hierarchical authority and exercise of strategic choice (Child, 1972) that the "subtle leadership" (Orton & Weick, 1990: 211) involved in network orchestration becomes essential. Second, in addition to processes, hub firms also influence networks through their recruitment activities (Doz et al., 2000; Kenis & Knoke, 2002). By its strategic choice of partners, a hub firm can significantly change network membership (size and diversity) and structure (density and autonomy). Through such recruitment and brokering activities, the hub firm can control its network position, maintaining its centrality and status. These structural variables and their impact on innovation have been examined elsewhere (Ahuja, 2000; Powell et al., 1996); therefore, while acknowledging the important relationship between structure and process, we focus on the orchestration processes shown in Figure 1.

KNOWLEDGE MOBILITY

Innovation networks thrive as organizational forms when the sources of industry expertise are widely dispersed and the knowledge base is complex and expanding (Powell et al., 1996). The fundamental logic for the existence of such "or-

FIGURE 1
A Framework for Orchestration in Innovation Networks



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ganizations of organizations" (Provan, 1983) is that knowledge-creating resources have greater value by remaining independent entities rather than forming a hierarchical unity of command and that these resources can be accessed across organizational boundaries and then combined and deployed in a variety of ways, synergistically leading to enhanced innovation (Freeman, 1991; Grandori & Kogut, 2002; Powell et al., 1996). Thus, network advantages can substitute for monopolistic advantages of giant corporations presumed by Schumpeter (1942) as uniquely efficacious engines of innovation—but only if the distributed resources of the network are mobilized to be efficiently deployed across organizational boundaries. Here, innovative output calls for what Hargadon and Sutton term *technology brokering*:

> Ideas from one group might solve the problems of another, but only if connections between existing solutions and problems can be made across the boundaries between them. When such connections are made, existing ideas often appear new and creative as they change form, combining with other ideas to meet the needs of new users. These new combinations are objectively new concepts or objects because they are built from existing but previously unconnected ideas (1997: 716).

As orchestrator, the hub firm shoulders the brunt of the responsibility for enhancing knowledge mobility and leveraging competencies in the network. Enhancing knowledge mobility requires a hub firm to focus on three specific processes: knowledge absorption, network identification, and interorganizational socialization. Innovation arises out of new combinations of existing capabilities (Kogut & Zander, 1996; Schumpeter, 1961). Combining relevant technologies in novel ways requires the "ability to identify, assimilate, and exploit knowledge from the environment" or absorptive capacity at the network level (Cohen & Levinthal, 1989: 569), which essentially reflects a learning capability at the organization's boundaries (Lyles & Salk, 1996; Simonin, 1999).

Hub firms can also enhance knowledge mobility by reinforcing a common identity among network members. A common identity among network partners is essential to "motivate members to participate and openly share valuable knowledge" (Dyer & Nobeoka, 2000: 348), since it creates the "logic of confidence and good faith" (Meyer & Rowan, 1977) and provides the "cohesive force" (Orton & Weick, 1990) that are imperative for creating an environment for knowledge flow. Likewise, Brown and Duguid (2001) found that, in communities of practice, identity provides the bond that determines whether knowledge is "sticky," making it difficult to flow, or "leaky," allowing generous flow.

Finally, socialization (formal and informal linkages among network members [Brown & Duguid, 2000, 2001; Nonaka & Takeuchi, 1995]) is another process by which a hub firm can enhance knowledge mobility. The serendipitous nature of innovation makes it impossible to predict the exact nature and timing of innovation outputs and necessitates, within a network, broad socialization across organizational boundaries designed to increase social and relational capital (Ahuja, 2000; Kale et al., 2000; Lyles & Salk, 1996; Makhija & Ganesh, 1997; Shan, Walker, & Kogut, 1994). Through exchange forums and formal and informal communication channels both within and outside immediate organizational tasks, a hub firm can enhance socialization and promote knowledge mobility within the network.

Organizational networks for innovation challenge the conventional wisdom on the boundaries of the firm (Pisano, 1990), given the complexity of sharing tacit knowledge across firm boundaries while developing effective antidotes for opportunistic behavior (Ahuja, 2000; Kogut & Zander, 1992). The dispersed knowledge structure that induces collaborative networks also necessitates an enhanced capability within the network to learn and teach across organizational boundaries.

> *Proposition 1: Network innovation output will be greater the higher the level of knowledge mobility orchestrated by the hub firm.*

INNOVATION APPROPRIABILITY

Mobility of knowledge within a network promotes value creation. Yet the hub firm must take the next step to ensure that the value created is distributed equitably and is perceived as such by network members. Because such distribution is often complicated by problems of free riding and opportunism, appropriability is a central concern in the economics of innovation (Arrow,

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1974; Schumpeter, 1942; Teece, 1986, 2000). Free rider behavior occurs when an actor does not bring in the best ideas to the network but enjoys the benefits of the knowledge flow in the network, and opportunistic behavior involves taking away the potential commercialization of new ideas unfairly, or taking advantage of the openness of other actors in the network (Teece, 2000). As Doz et al. observe, in an R&D network "a legitimate triggering entity may be required to lessen the concerns of potential participants that the costs and benefits of collaboration will be shared 'fairly'" (2000: 241). This triggering entity is the hub firm.

Hub firms can ensure equitable distribution of value and mitigate appropriability concerns by focusing on the following processes: trust, procedural justice, and joint asset ownership. Evidence has repeatedly shown that the strength of an appropriability regime rests not so much on writing lengthy contracts and exercising litigation options (Macaulay, 1963; Williamson, 1985) as on relying on social interactions with partner firms and using trust and reciprocity, rich information sharing, and joint problem solving (Uzzi, 1997). In innovation networks, given the uncertainty of the innovation process and the tacitness of shared knowledge, a crucial element of network orchestration is to play the championing role in building trust levels and in communicating clear, preestablished sanctions for trust violation.

Further, there may be high variability in the outcome of research activities carried out by network partners (resulting from the high level of uncertainty in the innovation process) and differential benefits accruing to different firms in the network from the same outcome (Khanna et al., 1998). Kim and Mauborgne (1998) found that, in such situations, procedural justice has a strong, positive impact on voluntary cooperation, and it discourages hoarding of ideas.[2] Thus, a hub firm seeking to engage the best efforts of network members by strengthening innovation appropriability might employ several designing principles of procedural justice (Kim & Mauborgne, 1998), including bilateral communications, ability to refute decisions, full account of the final decisions, and consistency in the decision-making process.

Finally, studies of innovation networks reveal an abundance of equity joint ventures (Ahuja, 2000; Shan et al., 1994) and patent pooling (Hagedoorn, 1995). Such joint asset ownership between a hub firm and other actors in the network enhances appropriability through three means. First, it provides "a form of mutual hostage positions which mitigates incentives to shirk or to behave contrary to fiduciary responsibility" (Kogut, 1988: 43). Second, it creates a context for joint problem-solving arrangements typically consisting of routines of negotiation and mutual adjustment that flexibly resolve problems (Dhanaraj, Lyles, Steensma, & Tihanyi, 2004; Uzzi, 1997). Third, it enhances the commitment of actors toward shared goals and provides incentives for sharing rewards.

Proposition 2: Network innovation output will be greater the higher the level of innovation appropriability orchestrated by the hub firm.

NETWORK STABILITY

A network that is unraveling is not conducive to value creation or value extraction, so a critical orchestration task for hub firms is to promote network stability (Ebers & Grandori, 1999; Kenis & Knoke, 2002; Madhavan, Koka, & Prescott, 1998). Stability poses an interesting dilemma in innovation networks. On the one hand, being loosely coupled organizational forms, networks possess the twin virtues of adaptation and agility. On the other hand, excessive erosion of network ties can lead to instability, which, in turn, can significantly impair innovation output (Lorenzoni & Lipparini, 1999).

Network instability can occur in several ways, including isolation, migration, cliques, and attrition. Actors in a network can become isolated (because of network growth or adverse past experiences), and such actors may decide to sever their links to the network. Actors may migrate to competing networks, if they see these competing networks as producing more value for them. Some actors may choose to create cliques, reducing the thickness of their ties to the hub firm. Finally, owing to the loose coupling arrangement, networks are subject to attrition. The greater the instability, the lower the network's

[2] Distributive justice is the fairness of the decision outcome, and procedural justice is the fairness of the decision process.

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value creation capabilities (Lorenzoni & Lipparini, 1999).

As orchestrator, a hub firm can increase the network's dynamic stability (maintain nonnegative growth over time) in several ways: by enhancing reputation, by lengthening the shadow of the future, and by building multiplexity. First, a strong hub firm reputation of market leadership among new and emerging firms seeking legitimacy in the marketplace by linking themselves with such market leaders (Baum, Calabrese, & Silverman, 2000; Stuart, 2000) provides twofold support to the stability of the network: it discourages actors' attempts to disconnect ties with the hub firm, and it encourages the formation of new ties, both of which work to stabilize the network. Given high levels of outcome uncertainty typical in an innovation process, compounded by uncertainties of potential partner behavior, reputation provides the signaling effect of trustworthiness (Macaulay, 1963; Podolny, 1993) and is significant in attracting alliances and acquisitions (Dollinger, Golden, & Saxton, 1997; Michelet, 1992).

Second, a hub firm can fortify reciprocal behavior and make the shadow of the future an effective promoter of cooperation (Parkhe, 1993). Experimental evidence suggests that although noncooperation emerges as the dominant strategy in single-play situations, under iterated conditions the incidence of cooperation rises substantially (Rapoport & Chammah, 1965). Iteration improves the prospects for cooperation by encouraging strategies of reciprocity (Uzzi, 1997; Wasserman & Galaskiewicz, 1994). Through the expectation of reciprocity—and its corollary, anticipated gains from mutual cooperation—the future casts a shadow back on the present, affecting current behavior patterns. This bond between the future benefits a network member anticipates and its present actions is called the "shadow of the future." Network stability is enhanced the longer the shadow of the future is, or the thicker the nexus is between current moves and future consequences, since forward-looking expectations of gains hold in check proclivity toward agreement violations.

Third, a hub firm can build more robust relationships by promoting multiplexity. Network multiplexity is defined as two or more types of relationships occurring together (Kenis & Knoke, 2002). Increasing multiplexity (e.g., a hub firm undertaking additional joint projects with network members or encouraging other network members to do so) expands the scope of existing relationships, and as firms interact more broadly and deeply with each other, they better understand each other's capabilities and idiosyncrasies, leading to heightened network stability. This is consistent with Kenis and Knoke's observation that "multistranded relations reinforce the ties among the field's members, making them more resistant to dissolution than are ties in a single stranded network" (2002: 284).

Proposition 3: Network innovation output will be greater the higher the level of network stability orchestrated by the hub firm.

MOBILITY, APPROPRIABILITY, AND STABILITY

Thus far, we have described the three processes that a hub firm must orchestrate in innovation networks and their direct effects on network innovation output. There are, in addition, interactions among the three processes.

Knowledge Mobility and Innovation Appropriability

When sophisticated knowledge sharing occurs among autonomous firms, as in innovation networks, there is a natural tension between revealing tacit knowledge to partners, in order to promote mutual learning and innovation, and exposing oneself to vulnerability to opportunistic behavior from those partners (Kale et al., 2000; Pisano, 1990). The literature suggests that learning is strongly linked to the perception of trustworthiness between the parties, and the strength of relationships among organizational members dictates what is being learned and how well it is being learned (Brown & Duguid, 2001). When innovation appropriability concerns are high, firms hesitate to share knowledge and view the moves of network partners with skepticism, and effective learning does not take place in such an environment (Brown & Duguid, 2000; Inkpen & Dinur, 1998). Contrariwise, in an atmosphere of trust, openness, and commitment, appropriability concerns are low, and learning flourishes because firms are more willing to share their proprietary knowledge.

Proposition 4: Innovation appropriability in an innovation network will

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positively impact knowledge mobility in the network.

Network Stability and Innovation Appropriability

The appropriability regime in an innovation network will influence, and be influenced by, network stability. Research has shown that equity often plays a critical role in enhancing both the appropriability environment and the stability of relationships, since equity mitigates the competitive dynamics and opportunistic behavior that can lead to premature dissolution of alliances (Beamish & Banks, 1987; Park & Russo, 1996). In innovation networks, given the loose coupling structure, relational ties are highly sensitive to the strength of the network's appropriability regime (Teece, 1986, 2000). That is, if actors perceive that they are being exploited, they will withdraw their support to the network and break ties with those perceived to be exploitative.

This points to a mission-critical role of the hub firm as the orchestrator: maintaining a strong appropriability regime that is vital to keep existing actors in the network. Even though it lacks hierarchical governance, a stable network reinforces relational ties among network actors, thereby enhancing appropriability in the network. Put another way, concerns of network members regarding "fair" allocation of the costs and benefits of collaboration will be exacerbated in unstable networks; conversely, trust, procedural justice, and joint asset ownership will be more likely to ensure equitable distribution of value in stable networks. Processes that enhance reputation, the shadow of the future, and multiplexity not only induce stability in a network but also contribute to trust and openness within the network, thereby contributing to a strong appropriability regime within the network. Thus, the strength of the appropriability regime and the stability of the network are mutually reinforcing and will have a reciprocal relationship.

Proposition 5: Innovation appropriability will positively impact the stability of innovation networks.

Proposition 6: Stability of innovation networks will positively impact the strength of innovation appropriability.

DISCUSSION

> There is a danger in network analysis of not seeing the trees for the forest. Interactions, the building blocks of networks, are too easily taken as givens. Partly, this is because of the perspective of the network analyst, whose purpose is to focus on the forest. The interactions that make it up are only necessary as a starting point. Yet why interactions exist cannot be ignored when considering the role of networks in a theory of organization (Salancik, 1995: 346).

Interorganizational relationship studies have progressed at two levels: dyadic and network. Studies of dyadic alliances have often focused on the transactional level, relating partner characteristics to alliance processes. Studies of networks, with roots in social network analysis, have tended to focus on structures, relations, and outcomes. Certain imbalances have resulted from these foci, with the former types of studies deficient in addressing the embeddedness of firms and alliances in a larger socioeconomic context and the latter types of studies unable to satisfactorily address questions regarding *firm*-level strategies, processes, and behaviors. Interorganizational networks, after all, are composed of individual firms, and the next stage of theory development must embrace this player-structure duality by taking into account both the structural inducements and constraints of the network, as well as organizational action that perpetuates the network. The trees and the forest are both important to understand.

Such work, linking alliance literature and network theory, is already showing promise (Ahuja, 2000; Baum et al., 2000; Doz et al., 2000; Gulati & Gargiulo, 1999; Gulati, Nohria, & Zaheer, 2000), and our paper attempts to extend this stream of research. Specifically, we started with the widely accepted notion that at the center of many networks are hub firms and, further, that such firms play pivotal roles *through individual action* in the formation, growth, and success of their networks. Yet little research exists to systematically examine how hub firms create and extract value from their networks—in short, how they orchestrate. We believe this is a critically important yet underexplored issue in "building effective networks."

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Drawing on multiple bodies of related literature, we developed a framework for orchestration in innovation networks (Figure 1), consisting of managing knowledge mobility, innovation appropriability, and network stability. This paper includes four points of departure from extant research. First, we explicitly recognize and highlight the heterogeneity of actors in a network. Hub firms are different from peripheral actors (how? market leadership? size? reputation? prior ties?) and play vastly different roles—facts not typically recognized in the network literature.

Second, we shift the focus to action and process, as opposed to position and structure. We are, in essence, returning to Burt's (1992) provocative insight that position alone does not create the benefit, but the entrepreneurial approach of an actor (the hub firm) to turn the position into an advantage does. Although other studies have explored the relationship of network structural elements to innovation output (Ahuja, 2000; Powell et al., 1996), little has been said about how firms enjoying centrality deliberately and purposefully act to preserve, exploit, and manage the network.

Third, by considering the issue of stability and its ongoing management, we move from traditional static analysis to a dynamic analysis of networks, thus recognizing the reality of change in interfirm network relationships (Kenis & Knoke, 2002; Madhavan et al., 1998). This approach complements emerging research in network theory, dealing with the dynamics of network relationships influenced by existing structural conditions (Ebers & Grandori, 1999; Kenis & Knoke, 2002).

Fourth, we integrate different perspectives often discussed in isolation in the alliance and network literature, including knowledge mobility, innovation appropriability, and network stability. This joint consideration provides richer insights on network innovation output.

Some caveats are in order. We have referred to "orchestrators" and "peripheral actors" as though orchestration were a dichotomy and all nonorchestrators were peripheral actors. This may be an oversimplification, particularly in settings of high-density networks.[3] Further, we have limited our discussion to single-hub networks and have not explicitly considered the competitive dynamics found in multihub networks (Gnyawali & Madhavan, 2001; Gomes-Casseres, 1994). Also, we have focused on innovation networks. In other types of networks (e.g., supply-chain networks), the mobility and appropriability conditions may not be as strict, and it may be possible to apply the framework to other types of networks by relaxing the conditions. Although we focused in this paper on network orchestration and not on network design (Figure 1), clearly, the network recruitment processes may impact orchestration and, in turn, the network's innovation output. A more complete theory of network orchestration awaits detailed treatment of the entire framework. Indeed, as envisioned by Fombrun (1982), it is possible to simultaneously assess the impact of the advantages that emerge from a central position (structure) and network orchestration (process).

Empirically, a key opportunity for researchers is to tease out *the unique contributions* a hub firm makes, despite its lack of hierarchical authority. Consider knowledge mobility, for instance. For a given roster of network membership, even without orchestration by a hub firm, a base level of knowledge mobility might exist within the network. What incremental value do hub firms add in pulling together dispersed knowledge resources to facilitate technology brokering (Hargadon & Sutton, 1997) that leads to enhanced innovation (Grandori & Kogut, 2002)? Such research questions seek a peek "under the hood" of innovation networks and call for systematically replicated case studies and cross-sectional, time-series research design.

Further, although our framework includes fundamental processes involved in network orchestration, and thus may provide a good starting point, it does not consider issues of reverse causality. Does the process drive the outcome, or vice versa? Does network stability lead to improved innovation output (Proposition 3), or does innovation success lead to stable networks? There is definite conceptual and practical merit in moving toward testing more complex theories involving unanswered questions about causal-

[3] It is possible for small networks to operate without any hub player, for short durations. These tend to be high-density networks where a high level of interaction replaces active coordination by a central player. Our focus is on the more commonly found high-centrality, low-density networks, as is typically the case in innovation networks.

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ity, and future research could significantly raise the level of theory development in network processes by employing path analysis and causal modeling that may permit a deeper understanding of network orchestration.

Finally, our orchestration framework has several implications for managers in firms that have large networks. Recent data suggest that the number of alliances per firm has gone up significantly, and it is common to find large firms managing over 500 alliances simultaneously (Hagedoorn, 1995). Our framework provides a practical way of managing such large numbers of alliances. Rather than focus on managing the discrete set of alliances, firms may develop broad capabilities within their organizations to enhance knowledge mobility, innovation appropriability, and network stability. The potentially high impact of the appropriability regime calls for careful monitoring of the strength of the regime at the firm boundaries. By considering the key subprocesses in orchestration, we have advanced several steps for effective orchestration to enhance innovation.

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