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Towards technological rules for designing innovation networks: a dynamic capabilities view

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Abstract

Purpose – Inter-organizational innovation networks provide opportunities to exploit complementary resources that reside beyond the boundary of the firm. The shifting *locus* of innovation and value creation away from the "sole firm as innovator" poses important questions about the nature of these resources and the capabilities needed to leverage them for competitive advantage. The purpose of this paper is to describe research into producing design-oriented knowledge, for configuring inter-organizational networks as a means of accessing such resources for innovation.

Design/methodology/approach – This exploratory investigation conflates emerging constructs and themes analytically induced from a systematic survey of 142 scholarly and practitioner articles and 45 expert interviews with senior professionals operating in the biopharmaceuticals industry.

Findings – The findings identify seven theoretically and empirically grounded technological rules associated with effective inter-organizational networking for innovation. They embody evidence *ex post* of networking theory and practice. Based on van Aken's seminal work, they comprise design-oriented knowledge to provide a solution architecture of viable action options for managers, a priori, to purposefully design innovation networks. Collectively these rules represent a tentative taxonomy, a means of classifying design principles, to assist managers in navigating their decision-making processes.

Originality/value – This study demonstrates the need for explicit design-oriented knowledge for configuring inter-organizational networks. Finally, the implications of the findings for strategic management theory are discussed from a dynamic capabilities view. The significance of a dynamic capability which addresses the renewal of network-specific resources is highlighted.

Keywords Networking, Innovation, Pharmaceutical technology, Design and development

Paper type Research paper

Introduction

Competitive global business environments remain congruent with Eisenhardt's (1989) notion of high velocity and D'Aveni's (1994) concept of hyper competition, in which technological innovations are frequent and potentially path breaking. Under such

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dynamic conditions, the effective renewal of products/services and how they are delivered are critical capabilities for many high-technology industries (Bartlett and Ghoshal, 2002; Zahra and Nielsen, 2002; Lovas and Ghoshal, 2000; Markides and Geroski, 2003; Bessant, 2003a, b). This is a major concern for the traditional pharmaceuticals and emerging biopharmaceuticals sector where advancements in the field of genomics, proteomics, bioinformatics and biotechnology are increasingly of a discontinuous nature. This makes the development of innovative medicines a risky and expensive process that demands organizational capabilities conducive to radical innovation.

Research is beginning to illustrate how relatively novel organizational forms such as "networks" are being deployed to access new technologies and their associated know-how to improve innovation capacity (George *et al.*, 2002; Hagedoorn and Duysters, 2002). Such opportunities to exploit superior external knowledge resources often come with the promise of new products for new markets. The use of innovation networks has become a distinctive feature of the rapidly growing biopharmaceuticals sector. Liebeskind *et al.* (1996) in their study of new biotechnology firms (NBFs) consider three organizational options for sourcing scientific knowledge: internal sourcing via internal hierarchies, external sourcing through market exchanges and external sourcing through organizational networks. Granovetter (1985) and Powell (1998) provide a critique of the traditional hierarchies and markets viewpoint in suggesting that its use does not acknowledge the importance of the social dimension as a means of governing business exchange, which is often predicated on trust. Tidd (1997) points out that whilst the network concept appears relatively novel and able to overcome the "market vs hierarchies" debate, as a so-called "third way," it is echoed in earlier research by Rumelt (1972) in the 1970s and Rothwell's (1992) Fifth generation model of innovation. More recently, Chesbrough's (2003) notion of open innovation and Bessant's (2003a, b) idea of high involvement innovation also replay similar generic arguments regarding the use of networks and confirm their potential to create new value. Coombs and Metcalfe (2002) argue that whilst the pharmaceutical sector has traditionally enjoyed considerable organic growth as a result of their patents, intellectual property, technologies, marketing and production capabilities, today's competitive environment is demanding fundamental changes to the way they do business. In particular, they comment on the way in which these firms have avoided a reliance on external expertise in the face of new biotechnological advancements, and how in recent years this climate has forced them to combine, reconfigure, integrate and co-ordinate resources within what they have termed a "distributed innovation system."

A Dynamic capabilities view of biopharmaceuticals product development

Biopharmaceutical product development is reliant on complementary resources bestowed by different organizations in a wider network, which is often globally dispersed. Such networks may include universities, clinical research organizations (CRO), pharmaceuticals companies; small genomics research laboratories, independent financiers, proprietary technology providers and other NBFs. The pooling effect of resources as an organizational level activity has been portrayed in other high-tech industries (Håkansson, 1987) as a "network approach" to innovation (Bower, 1993). Unlike other approaches (e.g. resource dependency, transaction cost and agency),

it seeks to understand how the focal firm and its peripheries change the multi-player (or network) context through their interactions. Such new industry settings are shifting the *locus* of knowledge, learning and value creation beyond the boundary of the single firm and into the network, with important implications for its future management and organization.

The resource-based view (RBV) of the firm is a useful theoretical framework for understanding how such dynamics lead to competitive advantage (Barney, 1991; Nelson, 1991; Penrose, 1959; Prahalad and Hamel, 1990; Teece *et al.*, 1997). As a significant theoretical view in the field of strategic management, it concerns itself with resources as being critical to a firm's competitive advantage and long-term survival. Whilst importance is attached to all physical and organizational resources, special reference is made to knowledge and competence-based resources.

In connecting the RBV to dynamic market environments more closely, Teece *et al.* (1997) discuss the notion of "dynamic capabilities" through which managers "integrate, build and reconfigure internal and external competencies to address changing environments" (Teece *et al.*, 1997). As a body of knowledge that has progressed rapidly over the last few decades, it explores the nature of such capabilities, and their distinguishing characteristics. A main thrust of this literature argues that dynamic capabilities are essentially organizational routines deployed to alter a resource base by "acquiring, creating, shedding, integrating, and recombining existing resources to generate new value creating strategies" (Pisano, 1997). Whilst the functionality of dynamics capabilities is generic and applicable across business contexts, their value lies in the resource configurations they create and not in the capabilities themselves (Eisenhardt and Martin, 2000).

Like Preim and Butler (2001) in their recent portrayal of the limitations of Barney's RBV, Eisenhardt and Martin (2000) suggest that the RBV misjudges the *locus* of long-term competitive advantage in dynamic markets. In considering this suggestion in the context of biopharmaceutical new product development (biopharma NPD), it can be argued that innovation, and hence competitive advantage, cannot be simply manipulated from within the boundary of a single firm, as presumed by a traditional RBV perspective, but rather from within a network of heterogeneous firms. This poses questions concerning the nature of resources that exist in the space between firms and how they are leveraged. Such inquiries are relevant to operationalizing inter-organizational innovation networks effectively, a topic which to date has witnessed a significant lack of management research to produce design-oriented knowledge. Our research aims to contribute to this theme and deploys van Aken's ideas of generating design-oriented knowledge through the development of what he calls "grounded and field-tested technological rules" (van Aken, 2005).

This paper presents seven empirically and theoretically grounded technological rules associated with effective inter-organizational networking for innovation. These rules embody evidence *ex post* of networking theory and practice and form the basis of design-oriented knowledge for managers to purposefully design innovation networks. Collectively, they represent a tentative taxonomy, a means of classifying design principles, to assist managers in navigating their decision-making processes and devising appropriate network development strategies. It acts as a useful framework for evaluating current managerial practice and considering the range of possibilities available to guide future action. In doing so, it constitutes valuable transferable

knowledge to support improvements in innovation capacity and performance. The investigation conflates emerging constructs and themes analytically induced from a systematic survey of 142 scholarly articles and 45 expert interviews with senior professionals in the global biopharmaceuticals sector. The resultant synthesis is recommended for further field-testing to better inform the broader practice of managing innovation in an increasingly multi-player (or network) context. The managerial implications of each rule associated with designing innovation networks are considered. Finally, the strategic management propositions of the research have been discussed from a dynamic capabilities view (DCV), and in particular its failure to adequately address capabilities associated with the renewal of network-specific resources.

Methods

This research adopts van Aken's (2005) diagnosis of the discipline of management as a "design science" (similar to medicine and engineering) to be distinct from the "explanatory" sciences (similar to physics, chemistry and biology). He suggests the science of management is primarily concerned with the need to produce design-oriented knowledge via "grounded and field tested technological rules" based on Bunge's (1967) notion of "technological rules." van Aken (2005) argues that field testing these rules in the real world enables descriptive knowledge to be applied, and transformed into actionable design knowledge. This design knowledge provides a solution architecture composing viable action options for managers, and so an important antecedent to management practice.

His perspective corresponds with the framework of a "Mode 2" knowledge production system, in which knowledge is generated "in the context of application" (Gibbons *et al.*, 1994; Huff, 2000; Nowotny *et al.*, 2001). Mode 2 research is multidisciplinary and seeks to solve complex and relevant problems in the field, as distinct from Mode 1 research which is often disciplinary and drives further research enquiry, as is often evident in the natural sciences.

In our study, quantitative and qualitative data from two complementary research phases deploying systematic review (SR) and empirical semi-structured interviews are conflated. The resultant synthesis of seven empirically and theoretically grounded technological rules is recommended for further field-testing. The following sections describe each of the research phases.

Sample and procedure

Phase 1: systematic review. An extensive SR of the extant literature sought to identify key constructs influencing effective inter-organizational networking practice. The SR adopts an evidence-based approach to assimilating secondary data using peer review and formalized criteria, based on its principal use in the medical field. It has a defined protocol designed to provide transparency and an "audit trail" based on Tranfield *et al.* (2003) as follows:

- An initial investigation of the ABI Proquest database was undertaken through search strings using the keywords in Table I. This was conducted within a select list of international scholarly and practitioner journals in the management science field. The search resulted in a total of more than 1,500 articles, from which 142 articles were selected for further review based on

specific inclusion/exclusion criteria set in accordance with the research aims and objectives. A sector focus was imposed to include management research in the pharmaceuticals, biotechnology and biopharmaceuticals domains.

- A database of the included 142 articles formed an "A" list for subsequent quantitative and qualitative analysis.
- The "A" list was initially subject to demographic analysis to gauge deeper understanding of the nature and form of the dataset.
- Summaries of the "A" list articles were transferred onto data recording sheets for subsequent theme-based content analysis, open coding and generation of higher order themes.
- A synthesis of this extant literature led to emergence of major constructs which were subsequently conflated with Phase 2 of the study.

Phase 2: empirical study. The aim of this exploratory investigation was to gain novel insights into the growing practice of inter-organizational innovation. Therefore, 45 semi-structured interviews with senior professionals in the biopharmaceuticals field were conducted, initially to examine major shifts in management practice regarding:

- biopharma NPD over the past 20 years;
- inter-organizational innovation as an explicit NPD strategy;
- enablers and barriers to implementing effective inter-organizational innovation;
- how drug development specialists acquire new sources of knowledge;
- current and future challenges facing drug development firms; and
- support for the future of biopharma NPD.

This exploratory approach relies heavily on analytical induction which does not require probability-based sampling techniques, because an important aim of the study is to generate further avenues of research inquiry (Yin, 1994). The research sample, shown in Table II, was selected using a modified "snowballing" technique (Miles and Huberman, 1994), whereby the initial informants were identified by the research partners, for their high-profile responsibilities across organizational and disciplinary boundaries in a biopharma NPD context.

The interviews ranged from 45 minutes to 3 hours in duration, and where possible were tape recorded for subsequent transcription. In the small number of cases where consent for tape recording was not forthcoming, detailed notes were made during and after the interview. The transcriptions and notes generated a substantial dataset for qualitative analysis. A process of analytical induction using theme-based content

Table I.
Systematic review: keywords

"Keywords" for search string formation	
Social capital	
Innovation network	
Innovation and network	
Network* and (pharma* OR biotech*)	
Strategic alliance* and (pharma* or biotech*)	
Total number of articles reviewed	142

Type of firm	No. of firms	No. of interviews	Exemplar informants
Big pharmaceuticals	4	12	Vice president biology, head of bioinformatics, R&D manager, manager, capacity and resource planning
Biotechnology	3	10	Head of drug discovery, vice president, strategic alliances, vice president sales
Life sciences consultancy	4	10	Associate partner, director pharmaceuticals R&D, principal managing consultant, group head pharmaceuticals R&D Europe
Biotechnology professional association	2	4	CEO BioIndustry Association (UK), Director of Bioprocess UK, Business Development Director, CEO Regional Biotechnology Initiative
Academic institutions	6	9	Professor, senior lecturer, senior researchers
Total	19	45	

Table II.
The sample of respondents

analysis (TBCA) revealed six second-order themes induced from 34 first-order open codes. Generic themes materialized through the expansion and contraction of key constructs, based on coding instances within the personalized accounts of interviewees, which further refined the clustering process. In addition to this, corporate documentation and other archival records were also included for analysis where available.

Findings

Phase 1: systematic review

The SR protocol identified ten key constructs influencing effective inter-organizational networking practice for innovation, from the extant literature. Table III incorporates these constructs as a theoretical framework, and the outcome of a process of qualitative induction. Each of these constructs is briefly discussed in the following sections and subsequently conflated with the findings of the empirical study.

The full "A" list of 142 articles shows a relatively even split of European, UK and US published items. Furthermore, 102 of these items were empirically based, 15 presented explicit design guidance in relation to innovation networks and whilst 77 upheld a strong knowledge-based view, only ten discussed the research findings from a DCV.

Key constructs influencing effective inter-organizational networking practice for innovation	Number of citations	Percentage
Dynamic view	14	4
Process and structure	63	16
Unintended consequences	20	5
Heterogeneity	48	12
Openness and security	44	11
Connectivity	52	13
Learning and knowledge transfer	43	11
Relationship management	49	13
Continuous and discontinuous renewal	30	8
Complexity and embeddedness	26	7

Table III.
Theoretical framework

Dynamic view. A significant proportion of the literature discusses the use of networks and learning from a dynamic view that illustrates the changing nature of organizational ties over time. Networks are considered from an evolutionary life cycle perspective with different phases of development which happen over a period of time (Pyka and Saviotti, 2001; Kreiner and Schultz, 1993). For example, there is usually an initiation phase, growth phase, stability phase and then a maturity phase, whereby the network might spur new connections or perhaps the existing connections might become dormant, only to be rejuvenated with a change in context at a later point in time. The dimension of time acknowledges that whilst a network may have a life span, individual connections are not necessarily product or network development phase-specific and will eventually develop their own history and path dependencies (Orsenigo *et al.*, 2001; Powell *et al.*, 1996). Learning in networks is enhanced due to firm's increased opportunities to access new sources of knowledge through a variety of external linkages. Therefore, networked firms are conducive to developing their capacity to absorb knowledge from external sources (i.e. absorptive capacity) and organizational routines for doing so (i.e. collaborative capacity).

Structure and process. The outcomes of network organizational arrangements can be enhanced, if both the wider network and specific network connections are actively managed and structured from initial inception to end-of-life (Pittaway *et al.*, 2004). Whilst an active management approach engenders formality, it is prudent to overtly facilitate the conditions conducive to releasing the potential benefits often associated with the informal nature of networks. For example, Bessant and Tsekouras (2001) in their study of supply, innovation and learning networks articulate a framework of eight generic processes for actively managing network dynamics based on the work by Grandori and Soda (1995). These include network creation, decision making, conflict resolution, information processing, knowledge capture, integration, risk/benefit sharing as explicit processes to be managed.

Unintended consequences. Networks have emergent properties and creating conditions to foster serendipity can be advantageous in achieving both intended and non-intended outcomes. A good start might be to positively encourage social networking through planned attendances at various business conferences, industry forums, etc. with a view to using this platform to promote formal partnering (Kreiner and Schultz, 1993). It is important to realize that the foundation of effective networks will also emerge informally over time, but then a repertoire of processes needs to be undertaken which follows an incremental and sequential transition from loose conversations and discussions to defined contractual obligations (Powell, 1998; Oliver and Liebeskind, 1997). Managers in their role as "network architects" must recognize that there are opportunities to capitalize upon the emergent properties of network dynamics. This may require significant investments in time and other resources to build professional trust, respect and loyalty amongst various networked firms, with a view to this being a sound basis for future exchange.

Heterogeneity. Organizational networks in the biopharmaceuticals sector are becoming diverse as firms recognize that future sources of innovation lie beyond the boundary of the firm. Network building strategies are shaped by the increasing specialisation and fragmentation of scientific and technological knowledge in this sector's quest for complementarities and synergies between the offerings of different firms. This leads in turn to greater dependencies and integration of disciplines across

firm boundaries in an interactive innovation system (Swan *et al.*, 2002, 2005). Diverse inputs from within the network contribute towards creative exploration and the effective exploitation of ideas, which subsequently improve the outcomes achieved for the amount of resources invested (Oliver, 2004; Murray, 2004; Powell *et al.*, 1996). One way to achieve heterogeneity within a network is for organizations to gain preferred partner status within the sector communities (Dyer *et al.*, 2001). Having a reputation which attracts a plentiful supply of partners allows firms to exercise sufficient choice in selecting collaborators, and achieve higher levels of network involvement and access to a diverse and rich knowledge base (Powell, 1998; Florida *et al.*, 2003).

Openness and security. Firms operating in networks may experience a level of insecurity arising from knowledge sharing activities, which carry potential risks to their intellectual property rights (IPR). The mismanagement of such tensions can impose limitations on the amount of learning that might take place amongst network partners (Owen-Smith and Powell, 2004; Gargiulo and Benassi, 2000). Whilst the benefits of "openness" and reaching outside firm boundaries cannot be over-emphasized (Burt, 1997, 1992), a degree of caution and "closure" also needs to be exercised (Coleman, 1988, 1990). Consequently, networked firms will often devise mechanisms to ensure an appropriate level of security and closure, particularly if their interactions are due to exploitative activity, e.g. memoranda of understanding, consortium agreements, legal and non-disclosure agreements, exclusive licensing contracts, version control or proprietary access, etc.

Connectivity. Human connectivity that can be augmented through digital connectivity (internet and intranet) and its ancillary developments such as e-mail, file transfer protocol, user-generated collaborative cyber workspaces, social networking software, video/web-conferencing, etc. can deliver knowledge advantages (Belussi and Arcangeli, 1998). Good connectivity or heavyweight membership of a network often results in firms occupying multiple locations in a wider network. This high-involvement strategy can lead to other intangible benefits such as enhanced professional profile and reputation. In addition, it may result in increased adjacency to multiple channels of knowledge flow, enabling swift navigation through a diverse resource base (Kostova and Roth, 2003; Prusak and Lesser, 1999). Such high involvement can also be a bridging activity across what Burt (1992) calls "structural holes" in networks, and needs to be complemented with sufficient bonding level activity to foster communities of practice (CoP). This process of communalization will embed social structures in CoPs, often predicated on trust, which becomes an important co-ordination mechanism within inter-organizational networks.

Learning and knowledge transfer. Networks can benefit from engendering a dual approach to knowledge transfer in which learning is pursued in a both responsive and proactive manner. Therefore, the sharing of experiences between networked firms through the exchange of dialogue as a means of knowledge diffusion (Prusak and Cohen, 2001; Powell, 1998) is very much encouraged. The further construction of systematic measures (for example, co-publications and co-patenting) to diffuse the learning within networks is also strongly advocated (Owen-Smith and Powell, 2003; Murray, 2004; Orsenigo *et al.*, 2001; Powell, 1998; Powell *et al.*, 1996). In doing so, the network is able to endorse the view of "learning as participation" and is akin to CoPs, as separate from the view of "learning as acquisition" (Yli-Renko *et al.*, 2001).

Relationship management. Networked organizations can improve innovation outcomes by increasing relational strength (Nahapiet and Ghoshal, 1998) by promoting trust and flexibility through low levels of prescription. This, for example, means having shared norms, values, obligations and expectations which facilitate benevolence leading to achieving the intended outcomes (Adler and Kwon, 2002; Bolino *et al.*, 2002). In terms of enhancing flexibility, trusting relationships encourage informal monitoring and reduce reliance on formal governance mechanisms with high levels of prescription (Barney and Hansen, 1994). Networks with a high degree of relational strength can engender a high-reliability organization with improved levels of redundancy for greater flexibility and responsiveness to changing demands (Smart *et al.*, 2002; Newell *et al.*, 2004).

Continuous and discontinuous renewal. Networks are not static structures and as connections continually evolve, the resource pool in the network is renewed through the multiplicity of collaborating arrangements ongoing (Cross *et al.*, 2002). We can deploy the term "ambidextrous innovation" – the simultaneous pursuit of both incremental and discontinuous change (O'Reilly and Tushman, 2004; Tushman and O'Reilly, 1996) to describe the need for firms in networks to be linked in a multifaceted capacity. For example, firms involved in networks to explore specific know-how must also be cognizant of the potential to exploit existing capabilities within the same or different relationship. We use the term "Explo-ti-ring" – exploiting existing capabilities and exploring new opportunities (Uzzi and Lancaster, 2003) to describe this phenomenon. Simply being aware of these notions allows networked firms to make more informed and strategic decisions about how to best apportion their R&D investments.

Complexity and embeddedness. Complexity in the biopharmaceuticals sector often implies escalating advances in science and technology which demand firms to be part of a wider network to explore, understand, learn and exploit the underpinning knowledge (Owen-Smith *et al.*, 2002; Pyka, 2002; Frenken, 2000). Another dimension to complexity is that of structural complexity, occurring due to the inevitable embeddedness and nesting of different networks, further complicated by the various path dependencies of firms (Gulati *et al.*, 2000; Stevenson and Greenberg, 2000). Essentially, the key concern for networked firms is how to navigate from within these structures, the relevant learning and knowledge which has been generated (Powell, 1998). In such circumstances, it could be beneficial to consider a firm's connections as a strategic portfolio of collaborations that can be manipulated to identify knowledge and technology complementarities or synergies within a network.

Phase 2: Empirical study – expert semi-structured interviews

Figure 1 shows a scattergram which summarizes the TBCA of the 45 expert interviews, and consisted of transcripts, detailed notes, corporate documentation and other archival records. It illustrates a range of emerging themes and related sub-themes, indicative of the macro and micro-level considerations informing management practices linked with inter-organizational innovation.

The theoretical framework of ten key constructs derived from the SR process was used as an analytical lens to further investigate the empirical data and conflate the studies. The resultant synthesis identified seven theoretically and empirically grounded technological rules associated with effective inter-organizational networking for innovation. They embody evidence *ex post* of networking theory and practice and

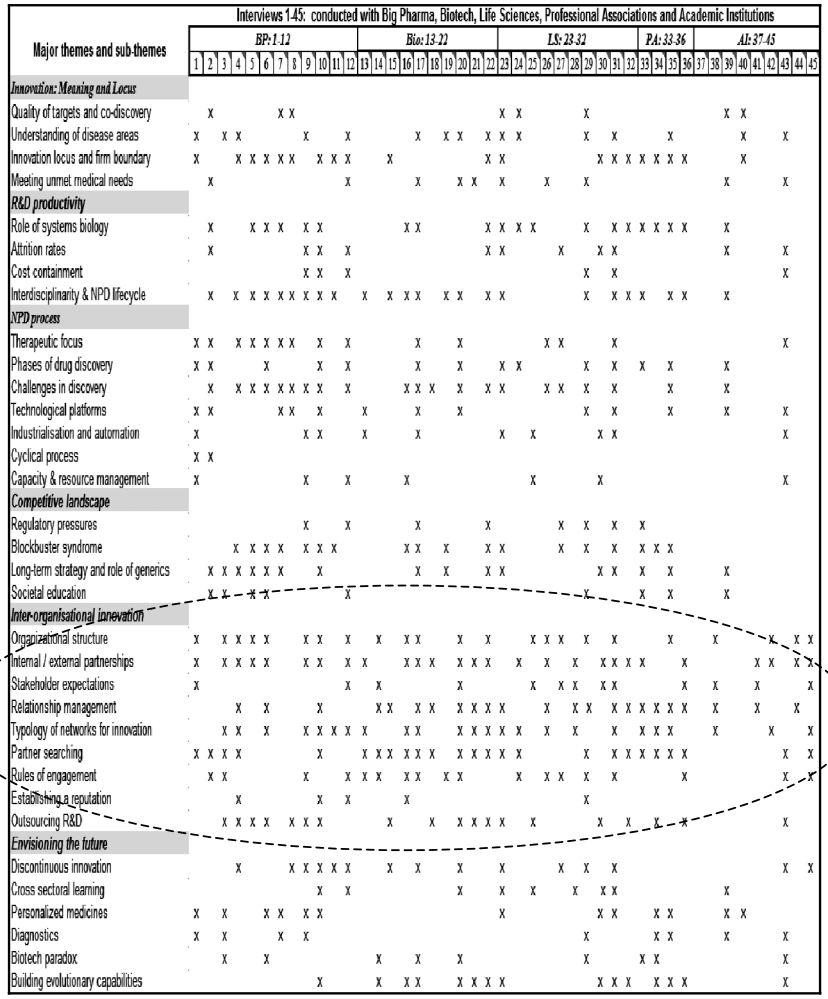

Figure 1.
Scatter plot of emerging themes

offer to support managers in a priori design of innovation networks. The rules are presented in Table IV and further field-testing through application is recommended as an important antecedent to future management action.

Overall, the research findings confirmed the assertions in the extant literature regarding the state of flux in the pharmaceutical industry, and the promises of the rapidly growing biopharmaceutical sector. They also confirmed the widespread aspirations and practice of inter-organizational innovation, as a viable strategy for long-term competitive advantage by creating new value through the combination and exchange of knowledge resources. This is exemplified by the rising number of biotech-BigPharma collaborations and the generally well networked bioscience sector. The evidence of what constitutes effective inter-organizational networking practice for innovation, signalled a disproportionate emphasis in favour of networking processes

Ten constructs sys. review	Exemplary empirical evidence	Seven emerging rules
Dynamic view	Emphasis on "disease centeredness" and "targeted treatments" results in holistic and long-term networks	Design for lifecycle
	Sophisticated multi-NPD phase collaborations engage a product "life-cycle" perspective, e.g. deploying co-development, co-marketing, co-promotion, in-licence, out-licence, hybrid "out-in" licensing, strategic alliancing, merger and acquisition	
	New business models and rules of engagement favour more flexible and multi-NPD phase collaborations	
	Venture capitalists seek evidence of commercialization partners in networks prior to funding (e.g. manufacturing, marketing, and logistics)	
Structure and process	New structures for co-ordinating co-NPD, e.g. Office of Alliance Management	Design for proactive management
	Inter-organizational collaborative capability considered as a core organizational competence	
	Seeking partners with successful history of co-NPD and collaborative capability is deployed as an explicit network-creation strategy	
	Strategic management of IP intensified external scouting in specific therapeutic/geographical areas for key scientists, professors and serial entrepreneurs	
	Quest for technological synergies and complementarities drives product innovation	
Unintended consequences	Senior management recognize benefits resulting from the unintended outcomes of formalised networks	Design for emergence
	Creating conditions for creativity and serendipity (e.g. acceptance of "under the bench" research)	
	Capitalising on existing social networks in the industrial community and geographical clusters	
	Informal and formal networks spin out of existing networks in a self-organizing manner	
Heterogeneity	Splitting and outsourcing of R&D functions forges new links with service and technology providers	Design for diversity
	Diverse partners in networks symptomatic of the increased fragmentation of disciplinary knowledge and division of labour, e.g. CRO, incubators, knowledge brokers, NPD teams, micro-biologists, medicinal chemists, nanotechnologists, proteomics scientists, contract manufacturers, bioinformatics, gene expressionists/sequencers, statisticians, computer scientists, bioinformatics, structural biology, combinatorial chemistry and high throughput screening	
	Emerging "Systems Biology" paradigm encourages greater multidisciplinarity	

(*continued*)

Table IV.
Emerging technological rules

Ten constructs sys. review	Exemplary empirical evidence	Seven emerging rules
Connectivity	Prolific network participation is a distinctive feature of the biopharma industry (e.g. discovery networks, developments networks, social networks, manufacturing networks, IP networks, regional networks, DTI mission networks, networking networks, professional networks/conference circuits)	Design for high involvement
Relationship management	A profile and voice in the community is a valued outcome of participation in various networks Search for strategic network partners within existing networks (e.g. access into social/professional networks of serial entrepreneurs, industry veteran's and key scientists) Strategic network partners (and/or serial entrepreneurs) are recruited to numerous scientific boards of new start-ups	
Learning and knowledge transfer	Adoption of knowledge management systems in inter-organizational NPD teams Dedicated time to pursue personal research interests through experimentation Desire to ensure learning is not divorced from the practice of scientists Using formalised industrial networks to explore new scientific and technological discoveries	Design for diffusion
Embeddedness and complexity	The embeddedness and overlapping nature of different networks is widely acknowledged Portfolio project management techniques are being considered to strategically manage co-NPD collaborations. For example, loosely coupled contracts for exploration (with low barriers to entry) and tightly coupled (high-specified agreements) for exploitative (high barriers to entries) activity	Design for strategic innovation portfolio
Openness and security	In-licensing IP and links with key scientists for tacit knowledge of disease progression and pathology Patents expiries on some blockbusters and me-too products within next 5-10 years is encouraging prolific scouting of IP for new niche product offerings	
Continuous and discontinuous renewal	Standardization, e.g. electronic note book enables sharing of experience, yet increased insecurity regarding knowledge spill-overs Complexity arising from engagement in product, process and technology-oriented networks IP insecurity addressed through links with executive education providers for bioscience professionals	

Table IV.

as distinct from their counterpart network structures. These included, for example, processes for selecting network partners, limiting knowledge spill-over in geographical clusters, co-learning, strategic positioning in multiple networks, recognising the importance of informal social ties in facilitating collaboration and the effective management of IPR.

Managerial implications: technological rules and design-oriented knowledge

Conflating the theoretical and empirical findings has identified a set of seven grounded technological rules, associated with effective inter-organizational networking for innovation. They also offer design-oriented knowledge for purposefully developing the structures and processes of effective networks.

Collectively these rules represent a tentative taxonomy, a means of classifying design principles, to assist managers in navigating their decision-making processes and devising appropriate network development strategies. It acts as a useful framework – an architecture – for evaluating current managerial practice and considering the range of possibilities available to guide future action. Figure 2 shows a conceptualisation of the relationship between the taxonomy of rules and management action. Further, field-testing of these tentative rules through application is recommended. The following sections briefly consider the managerial implications of each rule.

Design for lifecycle. The design for lifecycle rule conflates the theoretical construct "dynamic perspective" and management practices associated with increasingly varied and sophisticated co-new product development (co-NPD) strategies. The implication of this rule for managers is that they need to be mindful of the potential for collaborative opportunities within the entire product lifecycle during co-NPD strategy formation. Therefore, they should seek to ensure sufficient flexibility in their negotiations with potential partners to allow for multi-phased co-NPD involvement where appropriate. In other words, co-NPD strategies restricted to single phases of the NPD process, i.e. (design or development) hold the risk of limiting the potential to collaborate during

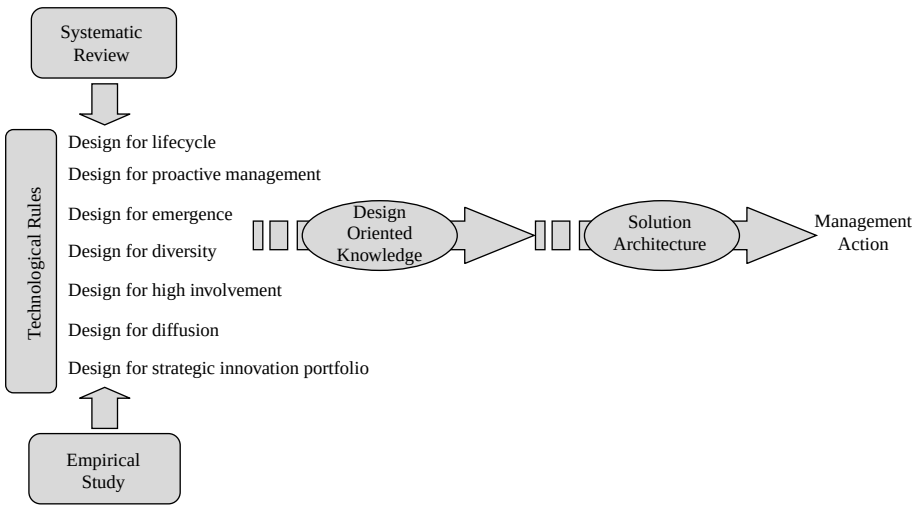

Figure 2.
Conceptualising the relationship between rules and action

other downstream activities (i.e. marketing and logistics) in a more holistic and profitable manner. This approach is echoed in the following quotation:

> We went from out-licensing of everything to out-licensing in agreements and asking a bigger piece of the pie, going through different business models, in turn developing bigger infrastructure, capabilities and then asking later on not only to co-develop, co-market and then became bigger ourselves (Head of Drug Discovery, Biotech).

Design for proactive management. The design for proactive management rule conflates the theoretical construct "structure and process" and management practices associated with the co-ordination of networks. For example, setting up formal structures (i.e. small departments and units) and the processes to manage external linkages with co-NPD partners is becoming increasingly common. The implication of this rule for managers is to recognize that the effective operation of networks demands a degree of proactive management. More specifically, this needs to be done with the appreciation of a generic process of network development at play (i.e. creation, operation and closure of external linkages), if the full benefits of innovation, such as identifying complementarities and synergies for exploitation purposes are to be reaped. In the words of one of our senior professionals:

> There is an orchestrated networking program going on (Alliance Manager, Biotech).

Design for emergence. The design for emergence rule conflates the theoretical construct "unintended consequences" and management practices associated with creating the conditions in which creativity and serendipity are encouraged. Often, this invites a recognition of the self-organizing characteristics of networks. The implications of this rule for managers is to acknowledge the informal channels through which innovation and learning take place which, by their very nature, do not lend themselves to formal management controls. Valuing and harnessing this informality will enable greater scope to capitalize on the *ad hoc* and emergent properties of network dynamics. This viewpoint was expressed by one of the research participants as follows:

> How you find out something is very *ad hoc*. Something someone says will spark something in someone else mind. We can only but try to create opportunities for serendipity (Head of Bioinformatics, Big Pharma).

Design for diversity. The design for diversity rule conflates the theoretical construct "heterogeneity" with management practices associated with increasing the levels of diversity to enrich the NPD process. This is partially due to the separation of some research from development activities, and the generally higher levels of complexity in new products, compounding the greater fragmentation of core disciplines and specialization. The implications of this rule for managers is to encourage diversity of NPD experience, skills, and disciplines in networks to enhance the creative potential for innovation, decision making and speed to market. The significance of diversity is clearly witnessed in the following quotation:

> We want a lot of inter-disciplinarity; a lot of transferable skills. People working in R&D should speak a diverse language. Since, everyone is looking at different levels of details and different levels of complexity, there are different priorities, different scales, different magnitudes, and different parameters. It's a very complex world (Head of Bioinformatics, Big Pharma).

Design for high involvement. The design for high-involvement rule conflates the notions of "connectivity" and "relationship management" and management practices associated with increasing levels of involvement of people with different backgrounds in networked NPD. Essentially:

> [Success] It all boils down to individual relationships. The whole area of relationship management is very tough. We should never underestimate how important relationship management is, or the individuals who are required for maintaining this. It falls down to the two people at the interface – the person in charge of the liaison from the BigPharma side with the person from the biotech (Alliance Manager, Biotech).

The implication for managers is to recognize that productive networks depend on prolific connectivity at both the structural level, (i.e. to create new "bridges" between people and organizations) and the processual level (i.e. to "bond" the new relationship through nurturing). For small bioscience firms, these heightened levels of connectivity allow them to develop both a voice and a profile in the community.

Design for diffusion. The design for diffusion rule conflates the construct "learning and knowledge transfer" with management practices associated with knowledge management within networked NPD teams. In the bioscience community, scientists are keen to ensure learning is not divorced from practice by confining it to the pursuit of formal qualifications. The implication for managers is to create practice-based learning opportunities within networks to facilitate knowledge transfer and not to limit learning to the traditional realms of the classroom. A key judgment that managers might seek to make is the degree of integration between the various networks that operate at the individual and firm level, to gauge the relative ease by which knowledge can flow through them. This will also assist the identification of further learning opportunities. The following quotation illustrates the potential for learning through networks:

> It dawned on us that we have to invest in developing phenomenal networking capabilities, to help us to learn. The stakes were really high, the top management team had to come in agreement and we had to develop this as mission critical to survive (Head of Drug Discovery, Biotech).

Design for strategic innovation portfolio. The design for strategic innovation portfolio rule conflates the constructs "embeddedness and complexity," "openness and security" and "continuous and discontinuous renewal" and the management practices associated with co-ordinating multiple and different networks, some of which are embedded (e.g. one off co-venture agreements nested within a strategic alliance) and serve different purposes. Whilst this situation is indicative of greater levels of involvement and openness in R&D, it also breeds insecurities regarding IPR issues:

> There is public and private research. Public research is publications driven. Within commercial private settings, there is privacy. Scientists are very nervous with their data. They always hold it close to their chest. If you want to apply for a patent for a chemical compound, then this data is a trace of your systematic research. For over 15 years there has been a discussion to let's make this lab journal electronic, but this has not happened. There is a very strong reluctance to publish data (R&D Manager, Big Pharma).

The implication for managers is to consider their firm's involvement in networks as a strategic portfolio of their collaborative efforts. In doing so, they can begin to distinguish different types of networks (i.e. strategic alliance, learning network, joint venture, etc.)

and their related purpose (i.e. explorative or exploitative) to better manage IP issues (e.g. security, risk and knowledge spill over).

Discussion: exploring a dynamic capability view

Network development capability

Clearly bioscience firms are evolving their inter-organizational networking capabilities in response to the challenges of creating new resources and value as they pursue product development. The industry represents a valuable "laboratory" for exploring the dynamics of innovation and particularly of skills, structures and processes around distributed innovation systems. In this section, we explore the notion of inter-organizational innovation from a DCV and try to draw out some implications for both strategic operations management theory and practice.

The last decade has witnessed an upsurge in research seeking to incorporate different strategic management perspectives in the field of operations management and strategy (Gagnon, 1999; Pandza *et al.*, 2003; Mills *et al.*, 2003; Miller and Ross, 2003). In particular, this work has begun to demonstrate the relevance of the RBV and DCV to improve future research and practice. Pilkington and Fitzgerald (2006) for example, see this shift as challenging the Porterian paradigm and moving towards a consideration of internal capability development for sustainable competitive advantage. They go on to suggest that studies conducted under this up-and-coming wave are "seeking a more subtle understanding of operations management by considering its practice in relation to strategy, context and resources." Arguably, the networked-innovation model outlined in this paper can help advance this emerging discourse by advocating new capabilities to co-ordinate network development relevant to strategy and operations in competitive global landscapes. In trying to do so, we stress the important role of strategic alignment and some "synergistic process of integrating business and operations strategic issues" (Anderson *et al.*, 1989) for significant impact on organization performance.

The research findings indicate that the industry dynamics in the burgeoning biopharmaceuticals sector are shifting the *locus* of knowledge and value creation within the supply chains. The *locus* is moving away from the firm to being spread over a wider network of heterogeneous firms. This change is becoming a dominant design feature of the industry and signals an urgent need to develop inter-organizational networking capability for the purposes of innovation.

The RBV explores the link between internal features of the firm and its performance (Barney, 1991). At the heart of the theory lies the argument that organizations are a bundle of resources, that are simultaneously valuable, rare, imitable and non-substitutional, or in other words "pass" Barney's VRIN test. Essentially, the RBV locates the source of competitive advantage inside the firm and associates rent generation with VRIN-qualified resources, controlled by the firm. To briefly summarize, the RBV discusses value creation through alterations in the firm's heterogeneous resource base that is considered to be idiosyncratic and sticky in relation to the firm itself, or in other words "firm-specific". Finally, the RBV deals with the business level question of how to compete, and is espoused to be a static theoretical perspective, as it considers resources at a specific point in a firm's history (Preim and Butler, 2001).

A relatively recent elaboration of the RBV of the firm, the DCV, addresses the underpinning organizational routines associated with future resource creation.

The DCV focuses on the capacity of a firm to renew resource bundles or in other words "integrate, build and reconfigure internal and external competencies to address changing environments" (Teece *et al.*, 1997). Whilst the functionality of such dynamic capabilities is generic, their value lies in the resource configurations they create and not in the capabilities themselves (Eisenhardt and Martin, 2000). In a manner not dissimilar to Henderson and Cockburns' (1994) conception of "architectural competence," this signals a co-evolutionary process in which the interaction of resources, competencies and capabilities within the firm are transformed into competitive advantage.

Major theoretical contributions to both the RB and DC views do not fully develop their discourse at the inter-organizational level. Fort example, Cohen and Levinthals' (1989) depiction of the crucial role of knowledge creation through endogenous R&D efforts and discussion of "absorptive capacity," combined with the adoption of technologies developed by others (outside the firm) for successful innovation, present a significant challenge to the traditional RB and DC view. Hagedoorn and Duysters (2002) also stress the importance of the efficient use of external resources and similarly form the basis of recent discussions by Day and Shoemaker (2006) of how companies develop "peripheral vision" – a propensity to exercise vigilance over the demands of their environments and so maintain a competitive position. The various contributions of these authors are alluding to the importance of knowledge and value creation being located outside the boundary of the single firm.

We suggest that, in the context of the fast changing biopharmaceuticals environment, the notion of the "firm" is a distinction that needs to be relaxed and elevated to an "inter-firm" conceptualisation. The various connections or relationships between firms in a wider inter-firm network can in themselves amount to being "network resources" and specific to the network itself. Whilst such resources exist in the spaces between individual firms, they still pass the VRIN test, yet are not controlled by any single firm and so present a different category of resource altogether, to that which is articulated by the traditional RBV. In this new category, the control of resources is considered to be distributed within the network.

A further distinction from the traditional RBV is that these resources, for many biopharmaceutical firms, come with the promise of future rents, rather than actual rents. As Bowman and Ambrosini (2003) indicate "because the processes of resource creation are not well understood, and because the identification of rent generating resources is problematic, we have to examine the processes of asset creation.". Owing to causal ambiguity, it is difficult to determine which particular activities, if enacted, will result in the creation of "true" resources that fulfil the VRIN test. Bowman and Ambrosini (2003) go on to suggest that it might be appropriate to investigate the activities and processes that should create assets (non-rent-generating resources) and may result in new resources (i.e. those that are rent-generating).

Arguably, in the biopharmaceuticals sector, dynamic capabilities associated with resource creation (both assets and resources) cannot simply be considered to be "firm specific," as some are likely to be enacted at a higher level, within a wider network at an inter-firm level. Subsequently, these capabilities reconfigure assets and resources that are both specific to the firm and specific to the wider network, through an interplay which may allow for certain resources to become more idiosyncratic and perhaps firm-specific over time. Therefore, the wider network contributes to knowledge and value creation by exhibiting dynamic capabilities. Whether or not the

process of new resource creation is triggered reactively or proactively, it may involve processes of co-ordination, replication, learning and reconfiguration (Teece *et al.*, 1997). In alluding to Bower's (1993) network approach we recognise the possibility of firms accessing resources not simply through direct relationships, but also via third-party relationships and contributors to the total resources of the wider network.

If we consider Makadok's (2001) argument that dynamic capabilities are built rather than bought in the market, and so are embedded in the firm, then we could argue for a similar process of building and embedding at the network level. Indeed, network connections and relationships can be considered to be network-specific assets and resources that display path dependencies and so are difficult to imitate. The theoretical implications of such a suggestion are that we relax our distinctions of what constitutes the firm and consider the network as a higher order entity that may also possess assets and resources, and so suggest a blurring between firm and network level strategic issues. The challenging role for the networked firm is the creation of new resource configurations from within a resource base that is controlled in a distributed manner by networked firms. In viewing such dynamic capability as one enacted and performed at the network level, there is some overlap with Dyer and Singhs' (1998) notion of relational capability development.

Increasingly, firms need to recognise that they are a "node" in a network and that they can create competitive advantage through the careful renewal of network connections and relationships. Indeed, new assemblies and bundles of such network resources could potentially generate new and unique value.

Conclusions and further research

Relatively novel organizational forms such as networks are being deployed to access new technologies and their associated know-how to improve innovation capacity. Such opportunities to exploit superior external knowledge resources for new product development have become a distinctive feature of the biopharmaceuticals industry. But, how does this process operate and how might firms build strategic competitive advantage through it? Much of the strategic operations management discussion has concentrated on developing strategies, structures and processes which work at firm level, although an important exception to this has been the extensive work on supply chains and networks. Whilst there is growing recognition of the importance of networks and discussion of concepts like "open innovation" across such landscapes, there is relatively little in the way of theoretical guidance about how to design and manage network-level operations.

In this paper, we have tried to make a contribution by exploring practices associated with operationalizing inter-organizational innovation networks, at both the strategic and operations management levels. We have developed a tentative framework architecture of "design rules" which might guide the process of network design for innovation. They represent a first pass at what might become more robust tools for practising managers to use, and have emerged through a combination of qualitative and quantitative research. However, there is clearly a need to develop these further and to replicate and strengthen the underlying research base.

In particular, further research is needed to validate and strengthen the architecture and to field test the model. It would also be important to extend the work to sectors other than bio-pharmaceuticals and perhaps to examine less turbulent environments (such as food or engineering) as well as similar sectors such as telecommunications.

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