Networks and High-Tech Innovation in Vancouver – An Application of Q-Analysis to ISRN Interviews

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Introduction

The purpose of this inductive study is to understand how technology entrepreneurs construct their network in pursuit of developing their new venture. A review of the literature recognizes that the structure of networks plays a role in firm or individual performance, and that network structures change over time (Aldrich & Zimmer, 1986; Birley, 1985; Elfring & Hulsink, 2003; Gulati, Nohria, & Zaheer, 2000; Jarillo, 1988; Larson, 1991; Lechner & Dowling, 2003; Nahapiet & Ghoshal, 1998; Ostgaard & Birley, 1994; Tsai & Ghoshal, 1998). Past research also tells us that in certain situations the position within a network structure is important (e.g. structural holes (Burt, 1992), centrality (Freeman, 1979)), network size and density (Borgatti, Jones, & Everett, 1998). In the high-tech setting there have been cross sectional studies that verify some of these propositions, as well as some that provide a descriptive model of different stages of entrepreneurs' network evolution (Hite & Hesterly, 2001; Yli-Renko & Autio, 1998), in addition to the occasional theoretical study (Larson & Starr, 1993). There remain few empirical qualitative studies that focus on the evolution of the network in conjunction with the development of the firm. Hite (2005) is a notable exception. However, her study investigates the evolution of individual relationship, not the simultaneous evolution of the firm and the network configuration as done here.

While these studies examine how a firm's position in a network may affect the available activities of the firm (and thus performance), or speak of the evolution of the network structure around the firm, they rarely integrate the activities and structure or compare multiple industry contexts. Prior research has also been dominated by statistical methods that describe the structure in aggregate mathematical terms, thus overlooking the role of specific configuration of actors in the network.

In this study we seek to better understand how the configuration of relationships immediately around a firm may impact its performance in context of its activities and industry. We use Q-analysis to reveal specific configurations of how actors are organized and involved in activities in relation to firm performance. This is an exploratory study, that employs Q-Analysis techniques, which "avoid the use of data transformations and summary measures," and are considered "best suited for exploratory research and hypothesis generation" (Jacobson & Yan, 1998). This study uses interview transcripts in which questions regarding the involvement of actors towards the development or access of specific resources are analyzed as proposed in Hakansson's network model (Hakansson, 1987, 1989) as source data.

The interviews analyzed were conducted as part of the 2001-2003 ISRN Innovation Survey in the new media and biotech industries in Vancouver. Subsets of firms are formed for comparison, by splitting the sample based on compound annual growth rate and industry. Conclusions are drawn in an attempt to link the performance of the new venture with the activities pursued through and the configuration of networks.

Literature review and propositions

The following sections outline some of the latest research on entrepreneurship and social networks in context of network structure, entrepreneurial action, and the interdependence of structure and activities. Each section concludes with a proposition related to theme of the section.

Structure:

Throughout the strategy and entrepreneurship literature, there are plenty studies that investigate the relationship between an organization's performance, and its position in a network structure (Baum, Calabrese, & Silverman, 2000; Bell, 2005; Gnyawali & Madhavan, 2001; Ruef, 2002; Uzzi, 1996). Two of the most popular, and conflicted arguments are commonly referred to as brokerage and closure (Burt, 2005). Both arguments have their strengths and weaknesses. In brokerage, there are arguably net benefits appropriable through being in a central position between disconnected parties through which one can govern a majority of arbitrage opportunities. The downside to such a brokerage position happens when one can not choose which opportunities to engage in or dismiss, and one is overburdened with being the hub of a demanding network, in which parties each have their own agenda. In comparison, closure involves extracting net benefits from being in a highly connected network, as a result of being able to rally resources more readily by getting others, who are already familiar with each other, to collaborate on one's behalf. In this case, the downside is experienced when the network is hard to mobilize and works against the firm's goals. This is not unlike herd-mentality that once tipped in one direction or the other, is difficult to redirect.

Much of the research on the relationship between organizational performance and network structure assumes the network structure is static. In most cases, the structure of the network is reduced to one or two aggregate mathematical measures. This reduction provides opportunity for vital details of the network context to disappear. The most common reductions of structure into singular measures are structural holes (Burt, 1992), centrality (Bell, 2005; Borgatti, 2005; Freeman, 1979), density (Gnyawali & Madhavan, 2001), and coupling or relational mix (Uzzi, 1996). Other noteworthy measures include network diversity (Ruef, 2002), and efficiency (Baum et al., 2000).

Use of any one of these measures is evolving in the literature, and incorporating more qualitative aspects of the nature of the network. For example, Uzzi's seminal research was based on a measure introduced by Baker (Baker, 1990), and combined the relative mix of the relationships with the relative strength of them in his studies of the NYC fabric industry (Uzzi, 1996), and SME lending rates (Uzzi, 1999). Uzzi's studies have since been replicated in the financial industry (Zaheer & Bell, 2005). Structural measures are particularly popular when using patent data, and can be augmented to include measures of tie strength by measuring counts of joint patents between firms (Ahuja, 2000; Cantner & Graf, 2006; Gnyawali & Madhavan, 2001). In a similar manner, research on VC deals and reputations (Podolny, 2001) considers multiple network level measures, namely Burt's measure of structural holes (Burt, 1992), and Bonacich's status score (Bonacich, 1987). Further notable studies include recent interfirm research in the biotech industry (Baum et al., 2000; Owen-Smith & Powell, 2004), and intrafirm research on structural and relational network measures in relation to managerial performance (Moran, 2005). At the end of the day, though, each of these studies reduces the rich and unique network context of each person or firm down to one or two aggregated measures. While the aggregate measures are showing incremental promise, this research attempts to leap beyond one or two-dimensional measures by explicitly addressing the complex configurations of actors, resources and activities through which the relationships are defined. In accordance with this research, we formally assume the following:

Proposition 1: The structural nature of the network in which a firm pursues an opportunity affects the success of the pursuit.

Resource exchange and development activities:

What are relationships if not shared experiences between actors, created through activities? Relationships are formed through the ability to relate to a common factor or engage in an exchange activity. Research on this dates back to the 1950's (Blau, 1957; Coleman, 1958; Emerson, 1962). The resources exchanges may be verbal or material, synergistic or positional. Exchanges may include information, knowledge, products or services, or capital of various sorts. Each relationship may also be defined by a functional exchange as well as a non-functional exchange. A functional exchange, for example, is a customer exchanging cash for products and services, while a non-functional relationship includes providing feedback or advice beyond what is expected in the functional agreement. This research assumes that the firm explicitly engages in functional and non-functional exchanges for the purposes of developing the firm, the products and services, and accessing external resources. While, theoretically, a firm can take action in isolation towards the development of itself, or its products and services, their activities are surely more effective if they relate to others outside of the firm. Practically, no firm is an island, and isolation from the environment leads to being overlooked, forgotten and closure.

Conventionally, individual relationships is characterized in terms of some measure strength, often a combination of trust, (fine-grained) information sharing, and joint problem solving (McEvily & Marcus, 2005; Uzzi, 1996), or variations Granovetter's proposed combination of time, emotional intensity, intimacy, and reciprocity (Granovetter, 1973). In contrast, this research considers the relationship in context of one or more activities and resources that bring the actors together. For example, while conventional network research might consider an investor to be in a strong relationship with the firm if they provide much more than just financial investment, the additional contributions are lost in the aggregation into the variable 'strength'. Instead, this research explicitly considers multiple types of exchange with the same partner without aggregating them into one-dimensional measures. The investor example may include one relationship for providing access to financial capital, and another for providing business advice towards firm development. Each exchange may involve sets of multiple actors, each of which is explicitly considered separately in this analysis. Using either the method and logic provided here, or that provided in past studies, the following proposition holds:

Proposition 2: The nature of individual relationships in the network through which a firm pursues an opportunity affects the success of the pursuit.

Interdependence of structure and activities:

A few entrepreneurship research streams have considered the interdependence of structure and activities under separate titles. The most well known in the management literature are probably enactment (Pfeffer & Salancik, 1978; Weick, 1979), effectuation (Sarasvathy, 2001), and structuration (Sarason, Dean, & Dillard, 2006). Each of these recognizes that while the opportunities and activities available to the entrepreneur are influenced by the network of relationships in which they exist, they are not entirely bound by this network. The entrepreneur can also change their network structure in the pursuit of opportunity. We agree with the many researchers who have built on these perspectives and see the entrepreneur as an integral part of the "individual-opportunity nexus" (Lechner & Dowling, 2003; Lechner, Dowling, & Welpe, 2006; Low & MacMillan, 1988; Shane, 2003; Shane & Venkataraman, 2000).

In essence, entrepreneurs are people who see unique opportunities to bring together resources, that others do not see (Burt, 2005), whether the resources are within or beyond the firm. Entrepreneurial activity may entail bringing together known resources providers in new ways, as much as it may entail drawing on resource providers not previously involved in the firms activities. In summary, while the network structure of related actors is relevant, and so are the activities pursued through the actors in the network, the structure and the activities are interdependent.

Proposition 3: To understand the degree to which the network structure and individual activities executed through the network affect the success of the pursuit of opportunity, they should not be considered independently of each other.

The methodology section below outlines the details of how cases were developed to analyze how structure, activities, and their interdependence play a role in the development of the firm.

Introduction to Q-analysis:

This study proposes the combined analysis of the network structure and the context of each resource development activity by using Q-Analysis (Atkin, 1972, 1977) in combination with Hakansson's network model (Hakansson, 1987, 1989). The Q-Analysis method specifically investigates the structural interdependence of actors, resources and activities. Hakansson's network model explicitly draws apart (i) the actors, (ii) the resources, and (iii) the activities involved in the exchanges as shown in **Figure 1**. Hakanson developed the network model with the "aim to describe and analyze technological development in companies, and the interactions with other companies and organizations." (Hakansson, 1989). One of his basic premises is that firms are not free or independent units, and that they represent part of a network, with which they are not fully acquainted, or in our case not fully connected. This network model is adopted because its focus on exchange activities provides an elegant bridge between coding the interview data into relationships with a richer resource and activity context than is conventional in network analysis, and being readily analyzable using Q-Analysis techniques.

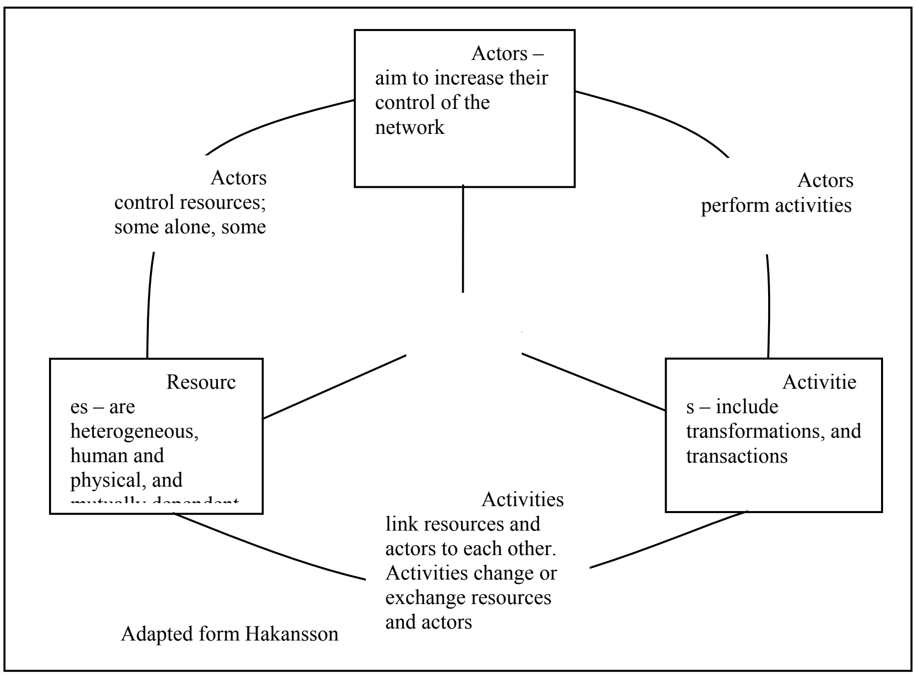

Figure 1: Hakansson's Network Model

Q-Analysis is an algebraic topology method, originally developed by mathematician R.H. Atkin in the 1970s as a method to describe and analyze structures (Atkin, 1972, 1977). It is also described as a "language of structure" that distinguishes between the structure (or "backcloth") and flows (or "traffic") (Gaspar & Gould, 1981; Gould, 1980). The uniqueness of Q-Analysis in contrast to network analysis and cluster analysis is "its extreme concern to avoid imposing structure on data as a methodological artifact" (Jacobson, Fusani, & Yan, 1993; MacGill, 1984). In other words, the algebraic processing of "data" by Q-Analysis lets "the data speak for themselves" (Gould, 1981), while the mental heavy lifting comes in interpreting the results.

In terms of understanding how technology entrepreneurs construct their networks in pursuit of developing their new venture, these features of Q-Analysis provide a tool for considering each relationship in context of the other relationships the firm has, and reveals the importance of configurations without aggregating 'data' into one-dimensional measures.

Generally, for Q-Analysis, data are collected in terms of sets of one kind (eg. a list of exchanges for all firms) that are characterized by sets of attributes or elements (eg. actors, resources, and activities involved). Unlike hierarchical definition sets, attributes may be related to multiple elements in the former set or none at all. Vice-versa, elements in the former set may be related to multiple elements in the latter sets or none at all. In Q-analysis terms, the former set is referred to the "backcloth" or structure, while the latter is the "traffic" or flow. The relationships between the two sets are captured in a matrix, called "incidence matrix" or λ (lambda). The matrix contains binary numbers to indicate whether elements (actors, resources and activities) are related or not and thus summarizes the structure of their relationships. In general, non-binary numbers may be used during the data collection process, but need to be binarized at some threshold level for further analysis using this technique. In Q-analysis terminology, each row represents one simplex, and each column represents a conjugate simplex. The analysis can be done with regards either, or both. This study considers only the conjugate simplex analysis in order to draw out configurations of the exchange attributes listed above, rather than configurations of answers to survey questions about exchanges.

The first algebraic step in the analysis involves calculating the Q-Chain matrix by multiplying the incidence matrix by its transpose, and subtracting 1 from each entry:

$$\text{Q-Chain} = \lambda\lambda^T - \Omega$$

where Ω has the same dimensions as $\lambda\lambda^T$ with all entries equal to 1. Only the upper triangle is retained for further analysis. This matrix contains the information about how many elements each simplex has in common, in other words the dimensions of the faces shared by the simplices.

The data for this study were formatted such that each response to a question by a firm is one simplex, and includes any combination of actors, resources, and activities involved in the exchange in question. In this study, the Q-Chain would tell which interview questions are shared by any given element, which is not particularly interesting. For conjugate analysis, the conjugate Q-Chain is simply the upper triangle of $\lambda^T\lambda - \Omega$. This is more interesting for this study, since it focuses on which elements (actors, resources, and activities) are shared by across the interview questions. While the remainder of the Q-Analysis description refers to the simplices, the same process holds true for the conjugate simplices.

The number of shared attributes between simplices is termed the q-level. Q-levels below 0 indicate that a simplex has no elements in common with any other simplex. From the Q-Chain matrices, Q-tables can be created that summarize which elements are involved in joining simplices for each q-level. This is done by starting with the highest available q-level and working towards the lowest. If the value in the diagonal of a simplex in the Q-Chain meets or exceeds the q-level under consideration, then it may be recorded in the Q-table at this level as the start of an "equivalence class". The simplex is considered q-connected to itself as indicated by the diagonal's value. Other simplices are added to this equivalence class if the other simplices are q-connected to themselves and to each other at this q-level. For example, if an off-diagonal Q-Chain entry meets or exceeds the current q-level, then the simplices corresponding to that row and column are q-connected. Simplices that are not q-connected with all the other simplices in an equivalence class start a new equivalence class at that q-level. The total number of equivalence classes at each q-level is recorded in the Q-count, typically in the second column of the Q-table, right next to the q-level. This column comprises the Q-vector, describing how many equivalence classes (sometimes called simplical complexes) are q-connected at each level. The Q-vector as a counterpart, called the obstruction vector, that tells how many disconnects there are at each q-level, to create one q-connected equivalence class. The obstruction vector, Q*, is simply Q - 1.

The resulting Q-table provides detailed information as to which simplices are connected at all q-levels, without prescribing how many clusters they should fall into, or which threshold q-level to consider for whether they are connected or not. In other words, they indicate the degree to actors, resources and activities are more prevalent in the network, and at which levels they are connected to each other and can be organized into coherent sub-groups (aka equivalence classes). The Q-Chain matrix also provides for valuable input into network graphic software to visualize the connections between simplices. Network visualization is best done by selecting a q-level of interest, and then binarizing the entries in the Q-Chain's matrix to either 1 if they are equal or greater than the q-level, or zero if not. In this case, the matrix provides a correlation table of all actors, resources, and activities if they are connected to at least one other such element.

The resulting network graph indicates which elements are directly and indirectly q-connected at the chosen q-level. This permits inclusion of potentially interesting peripherally connected elements that would typically be omitted or regressed away by conventional quantitative methods. In many cases, it is particularly these ‘outliers’ that provide insight into the overall network precisely because they are not (well) connected. Q-Analysis thus allows for structures to emerge from the data including the potentially more interesting configurations that statistical methods would have deemed as outliers and hidden in the regression to a mean. As quipped by A. Levenstein: “Statistics are like a bikini. What they reveal is suggestive. What they conceal is vital.”

Method

Sample selection:

Interview transcripts from 114 interviews conducted were provided by members of the Centre for Policy Research on Science and Technology (CPROST). The interviews comprised the Vancouver part of a cross-Canada research project on innovative industrial clusters conducted in collaboration with the Innovation Systems Research Network (ISRN). The interviews were conducted with organizations in the biotech and new media industry, including technology-based firms (54), civic associations (13), government branches (10), educational institutes (9), venture capital firms (5), and contract service providers (23). For 24 of the 54 technology-based firms, compound annual growth rates (CAGR) for the preceding 3 years of revenues were available through the interview process or through secondary sources, if not through the interview process. Of these 24 technology-based firms, 11 were in biotech, and 13 in new media.

The two sets of firms have are similar in size (11 vs. 13) and composition. Each has one firm with over 400% CAGR, and 2 to 3 more with over 100% CAGR. The majority of the firms in each sample exhibit moderate growth rates. Both industries also have one to two firms that actually shrank. biotech has two firms that effectively shrank down to just the corporate officers and effectively experienced a total loss of revenues. Sets of the 3 lowest performing firms in each of the industries were created to compare against each other and the 3 highest performing firms in their respective industry. The low performers included the shrinking firms as well as 1 or 2 mediocre growth firms (below 15% CAGR). We feel that these are reasonably comparative sub-sets in the sample for a sound basis of comparing network use and configuration using Q-Analysis techniques.

Data coding and analysis:

Interviews were conducted with senior executives or the founders of the firms who could speak on behalf of the firm in an innovative clustering context. Each interview was comprised of 95 questions relating to the company background, research strategy and innovation, supply chain relationships, (extra-) regional/infrastructure factors, relationships to public research institutes, local relationships, future projections, customer feedback and intellectual property. Interviews to the 77 firms were selected at random to explore (i) the degree to which the replies are relevant to this research by way of how the questions were phrased, (ii) the degree to which questions were answered consistently across firms, and (iii) the degree to which actors, resources and activities were mentioned in the replies. After coding replies to 25 firms an initial coding scheme had been developed, by coding each relevant answer at face value. The initial coding scheme was reviewed and some labels were merged appropriately to create a more concise, yet still accurate coding scheme. For example, the products and services labels were merged into one "Prod/Svc" label, and the 'grow' activities were rolled in with the 'develop' activity. Overall, only 14 of the 95 questions were relevant and answered with even a modest degree of consistency across the random sample.

The interview questions that emerged from this process were reviewed for high response rates and their ability to support multiple configurations of actors, resources, and activities. The list of questions was reduced from 14 to the following 5, which were each answered by at least 79% of the firms, and directly related to configurations of relationships in relation to firm development, product or service development, and accessing capital:

- What is the relative importance of the following local sources of innovative ideas for your product, service and process development? [1=not important, 5=most important] (option of 11 sources)
- What is the relative importance of the following non-local sources of innovative ideas for your product, service and process development? [1=not important, 5=most important] (option of 9 sources)
- What are the most important inputs to your company?
- What are the most important factors in the local/regional economy that contribute to or inhibit the growth of your firm? (option of 9 factors)

- What are the major sources of finance for your company? (angel investors, family friends, internally generated funds, funds from parent or affiliated firms, banks, venture capital, equity investment (IPO's), government loans or subsidies, other).

Each of these questions explicitly addresses a combination of activity and resource (eg firm development, product/service development or access to cash), and calls for a list of the actors involved. Each of the replies by each of the firms comprised one simplex, with a total of 21 attributes coded according to the actors, resources and activities mentioned, for a total of 120 simplices or 21 conjugate simplices. Conjugate Q-tables were produced using the Q-Analysis techniques described above for 6 subsets of data and are presented in **Appendices**

Appendix 1. The subsets include only biotech firms, only new media firms, only the top 3 biotech firms, only the bottom 3 biotech firms, only the top 3 new media firms, and only the bottom 3 media firms. These Q-Tables were produced in order to consider the actor-resource-activity network structure separately for each industry to allow for comparison within and between industries. This allows for inferences to be drawn regarding the structure and performance of firms within an industry and more generally (across industries).

To assist with the interpretation of the actor-resource-activity data, the network diagrams for Q-Chains at q-level 1 were generated for the top and bottom 3 firms within the biotech and new media industry, respectively, and may be found in **Appendix 2**. The elements were laid out using Krackplot 3.3 (Krackhardt, Blythe, & McGrath, 1994) according to the built-in multi-dimensional scaling algorithm. In one case (biotech top 3), a few elements were manually moved to improve clarity without substantially changing the overall layout. Visually, the elements are differentiated as rectangles for actors, ellipses for activities, and borderless labels for resources.

Results

Interpretation of Q-Tables

Since all the questions relate to the development of the firm, development of products or services, or access to cash, it is not surprising to see that the most prevalent element in the Q-tables is ‘development’, regardless of which resource. The business models at the foundations of the biotech and new media industry are apparent in **Q-Table 1** and **Q-Table 2**, in that the biotech firms place emphasis on access to proprietary or private knowledge (“Priv-Knowl.”) in the race towards competitive intellectual property (IP). In comparison the new media firms place emphasis on private opinion (“Priv-opinion”), such as customer feedback that lead to greater market traction in the race for market share. Private opinion does not register at all with biotech firms, and conversely private knowledge does not register with new media firms. While the new media firms are not as explicit as one might expect about the importance of generating revenue early, they clearly place less emphasis on using public markets to access cash (q-level 4) than the biotech firms in the sample (q-level 8).

Both types of firm indicate moderate mentions of access to physical infrastructure as being important to the development of the firm (q-level 4). In the case of biotech, it is implied that the infrastructure belongs to the university, while in the case of new media the infrastructure in question refers to the internet backbone. The dependence of biotech firms on access to universities becomes clear when considering the q-levels at which universities are mentioned (q-level 22) versus customers (q-level 12). This reinforces the observation that biotech firms compete on acquiring IP, not customers. Comparatively, the new media firms are connected to universities at a lower level (q-level 7) than customers (q-level 30), reinforcing the observation that they compete on acquiring customers, not IP.

Considering the location of these respective key players in each of the Q-tables, both share an equivalence class with 'develop' at high q-levels, but not with a specific resource. Since the 'develop' element is always associated with a resource, by virtue of the coding process, this tells us that these players are involved in both the firm and the product/service development. Considering for the moment only the biotech firms, the involvement of universities (q-level 7) is quickly followed by the inclusion of 'firm' and 'employees' in the same equivalence class (q-level 21), as well as the involvement of investors as a separate equivalence class (q-level 21). Product/service development is likewise of great importance (q-level 20), but not shared by all those already involved in firm development. new media firms face a somewhat similar combination, in that 'firm' and 'products/services' are highly connected elements (both at q-level 20), but do not share the same equivalence class.

The key difference between these core development networks is that biotech firms have a higher dimensional connection to investors (q-level 21), than do new media firms (q-level 13). However, the functional role that investors have, of providing cash, only appears at q-level 15 for biotech firms, while for new media firms, cash resources are slightly more connected than even the investors (q-level 14). Implied in this configuration is that investors play a role well beyond just providing cash for biotech firms, while new media firms see them more as one of many sources of cash. One of the questions arising from this overview though, is “What role do investors play, if not just to provide access to capital?”

The Q-analysis was run separately for the top 3, and bottom 3 sub-sets of firms in each industry, of which the results are shown in Q-Tables 3 through 6. This was done to explore if there are notable differences in the configurations that might relate to the performance of the firms. Across the top and bottom 3 performing firms in biotech, some differences immediately stand out. The top 3 biotech firms are q-connected at q-level 5 with employees and firm development in one equivalence, investors in another, and products/services in a third equivalence class. Universities are only q-connected at q-level 4, when they appear within the firm development equivalence class. These firms place firm and product/service development at the same priority or q-level, above their connections to universities.

In comparison, the bottom 3 biotech firms are q-connected at a higher level with universities than anyone or anything other than ‘development’ itself. The next most connected resource is the firm, which is q-connected at q-level 5, along with employees, as an addition to the universities and development equivalence class. At q-level 5, investors also make their most connected appearance as a separate class, similar to the top 3 biotech firms.

These differences between the top and bottom 3 biotech firms indicate that the lower performing firms are either still focusing on developing IP with universities and are pre-commercial, or that their mixed priorities and university dominated relationships are holding them back from attending to getting employees and external parties involved on product/service development, and thus revenue generation. Considering the customers, we see that the top 3 biotech firms only maintain q-connectivity at q-level 3 out of 11, but this is nonetheless higher than their appearance at q-level 1 out of 9 for the bottom 3 biotech firms.

In summary for comparing the Q-tables for the top and bottom 3 biotech firms, higher performing firms place the greatest emphasis on firm development and commercialization of IP into products/services with the aid of employees and investors, followed by maintaining relationships with the universities and then customers. Lower performing biotech firms, on the other hand, place the greatest emphasis on relationships to universities, followed by a focus on firm development with the aid of employees and investors, which in turn is followed by consideration of product/service development, leaving relationships with customers effectively as a footnote to everything else.

In interpreting the Q-tables for the top and bottom 3 new media firms, the business model of focusing on customer needs and gaining market traction is immediately evident in comparison to the biotech's competing on IP. Particularly for the top 3 new media firms, the customers are q-connected at q-level 6 as their own equivalence class, and then at q-level 5 in combination with development in general. At q-level 4, employees are added to the same equivalence class, and products/services appear as their own equivalence class. The firm appears shortly after at q-level 3 as part of the main equivalence class, along with the competitors, thus further emphasizing the competitive context in which new media firms achieve market traction or perish. Access to cash is not explicit until q-level 2, which indicates that these firms are more focused on sustainable value creation for customers in a competitive context, than revenue extraction from an existing customer base or raising cash to fund development in lieu of revenues.

In comparison, for the bottom 3 new media firms, customers appear as their own equivalence class at q-level 4, along with an equivalence class of firm, employees and development, another of only investors, and another of only cash. Customers are also not the most connected element. Another interesting point of difference between the top and bottom 3 new media firms is the involvement of government organizations and universities for the bottom 3 firms, in place of the competitive context in the top 3 firms. In fact, competitors are not connected to the bottom 3 firms until q-level 1, whereas government and university relationships are not mentioned at all for the top 3 firms.

In summary for comparing the Q-tables for the top and bottom 3 new media firms, higher performing firms have an intense focus on leveraging their employees to serving the customers needs in a competitive context. On the other hand, lower performing firms appear spread thin between pursuing simultaneous firm development, product/service development and accessing cash, while catering to the demands of bureaucracies whose value-add is questionable, and potentially at the expense of neglecting the competitive context.

Interpretation of Q-Chains

While the above interpretation of the Q-tables considered the dimensions (q-levels) of each of the relationships, interpretation of the Q-Chains provides a more detailed view of the structure of the relationships between elements. A q-level of 1 was chosen to generate the Q-Chain diagrams since it provides a comprehensive overview of the network structure without getting too cluttered.

Overall, the biotech Q-chains mirror the results in the biotech Q-Table, in that the top 3 firms have constructed and are using their network with an emphasis on developing products/services for customers in a competitive context by involving their employees and relationships to universities. They are also explicitly getting investors engaged in the product/service development, with perhaps the implicit assumption that if the firm successfully services their customers, that it will be a more profitable or sustainable investment for them.

In contrast, the bottom 3 firms appear to have "too many cooks in kitchen" and not enough understanding of the customers they are in competition for. Investors play a more active role in firm development than product/service development, which suggests they are more in it for a quick sell of the firm, than they really contribute to the operation of the business. There is a lack of consideration of what competitors are doing. These results are mirrored by the previous interpretation of the Q-Table. Now also visible, is their apparent inability to maintain a relationship with universities without the involvement of consultants. This indicates that they may not have the best expertise in-house to understand the research being pursued in universities, and certainly have a serious disconnect between customers and product/service development.

Overall, the top 3 new media firms have two distinct networks they use, which is clearly visible here, but not so apparent in the Q-Tables. On the one hand, they access some initial cash through personal networks. On the other hand, they have a highly connected (q-level 3) yet neatly exclusive core set of relationships they use to focus on product/service development to presumably generate revenues in a competitive environment, hence the lack of further mention of cash. This core set is augmented by the involvement of suppliers in firm development, and the peripherally connected investors. Taking a closer look at the investors in the incidence matrix reveals that they are linked to firm development with employees, and accessing cash with family and personal networks. While investors are not exceptionally well connected in the operation of the firm, they may still play a bridging weak ties role (Granovetter, 1973).

In contrast, the bottom 3 new media firms operate in an entirely different network. While the dominant resource being developed is also the product/service, there is exceptionally high engagement in accessing cash, and firm development involves not just employees, but also customers and competitors, with no mention of suppliers. The involvement of universities and government agencies for product/service development is a potential distraction from incorporating customer feedback and keeping an eye on the competition. Most of all, the investors appear to have unusual relationships beyond providing access to cash. They are also involved in the product/service development with the universities and government agencies. As indicated by their lack of connection to the customers or firm development, they may have an inaccurate understanding of what it takes to build a successful firm, are binding prescious firm resources to slow moving bureaucracies, and are more interested in selling their shares in the financial market.

Comparing biotech and new media q-chains, we see that in both cases, the firm is primarily a vehicle fueled by cash with a focus on developing a product/service. The observations indicate that in investors in biotech play a more constructive role than in new media. For biotech, one explanation may be that sustainable business models are as yet unknown in biotech and require the constructive input of everyone who might be knowledgeable in the commercialization of biotech research. Alternatively, they may have a longer term view on realizing a return on their investment or be looking for intangible rewards such as the claim to having cured cancer. For new media, one explanation may be that investors have seen concurrent IPOs, acquisitions or other exits and are seeking quick returns from their involvement of the firm to the detriment of those trying to serve the customers in a competitive context. An alternative explanation may be that new media firms just were not performing as well as expected after the turn of the millennium, and that investors had circumstantially gotten more involved in salvaging value before a complete collapse.

Despite the differences between the use and structure of relationships in the biotech and new media industries, there are points that the top and bottom tier performers have in common across industries. In both industries, the top performers are able to leverage the motivations of their cash sources to increased benefit. Investors in these top firms are, for the most part, hands-off about firm development, but constructively involved in product/service development. There was surprisingly little mention of government relationships by top performers, which puts the viability of their programs under question. It is entirely possible that these relationships exist and are beneficial, but are neglected or considered trivial in comparison to everything else. Unique to the top performing firms is the marginal involvement of suppliers. These firms may be able to make better use of new technologies their suppliers provide, or use their suppliers as competitive sources of information. Last, but certainly not least, the top performers were acutely aware of their competition and considered them integral to the development of the firm and product/services.

In contrast to the top performers, the bottom performers in both industries were explicit about their cash flows from customers, indicating that they may be living hand-to-mouth. Furthermore, their cash sources were not kept separate from firm or product/service development, indicating there may be several conflicts of interest. The investors were mentioned mainly in their functional role, but could be consuming valuable management resources if their agenda is in conflict with that of management. Their relationship to government and universities indicates they may be spending considerable resources trying to re-focus firms from bureaucratic public support to market competition. An alternative explanation for this relationship may be that the investors manipulated the firm to be connected to the public organizations in interest of keeping the firm alive long enough for them to get their investment back out. This latter explanation is more likely considering the negligible mention of competitors and conflicted understanding of whether the customers are there to serve the firm by providing revenues, or if the firm is there to serve the customers by providing value.

Discussion and conclusion

The interpretations of the Q-Tables and Q-chains show how the performance of a technology based firm can be contingent not only on which actors they are connected to, but also what exchange (aka. resource development activity) brings them together, and how each exchange fits in relation to the rest of the network structure and use. A speculative extension may be that poor performance firms also can not change one relationship at a time in order to turn around, and that they may be bound to a major deconstruction of their network before building it back up in a more productive manner. If all relationships were considered equal, as done in conventional network analysis, the context of the actors coming together would have been lost (eg. firm development, product/service development or accessing cash). For example, the role that consultants play specifically in relation to the relationship with the university may have been entirely overlooked, and the multiplicity of roles the investors play may have been left unrevealed.

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Appendices

Appendix 1: Q-Tables

q-level	Q	Q*	Equivalence Classes
41	1	0	{develop}
22	1	0	{universities, develop}
21	2	1	{firm, employees, universities, develop}, {investors}
20	3	2	{firm, employees, universities, develop}, {investors}, {prod./svc.}
16	4	3	{firm, employees, universities, develop}, {investors}, {access}, {prod./svc.}
15	5	4	{firm, employees, universities, develop}, {investors}, {access}, {prod./svc.}, {cash}
14	4	3	{firm, employees, investors, universities, develop}, {access}, {prod./svc.}, {cash}
12	4	3	{firm, employees, investors, universities, develop}, {customers}, {access, cash}, {prod./svc.}
10	3	2	{firm, employees, customers, investors, universities, develop}, {access, cash}, {prod./svc.}
9	4	3	{firm, employees, customers, investors, universities, consultants, develop}, {partners}, {access, cash}, {prod./svc.}
8	5	4	{firm, employees, customers, investors, universities, consultants, develop}, {partners}, {government}, {access, cash, market}, {prod./svc.}
7	4	3	{firm, employees, customers, suppliers, investors, universities, partners, consultants, develop}, {government}, {access, cash, market}, {prod./svc.}
5	3	2	{firm, employees, customers, suppliers, investors, universities, partners, government, consultants, develop, access, priv-knowl.}, {prod./svc.}, {cash, market}
4	3	2	{firm, employees, customers, suppliers, investors, universities, partners, government, consultants, develop, access, priv-knowl., phys-struct., cash}, {prod./svc.}, {market}
3	3	2	{firm, employees, customers, suppliers, competitors, investors, universities, partners, government, consultants, develop, access, priv-knowl., phys-struct., cash}, {prod./svc.}, {market}
2	3	2	{firm, employees, customers, suppliers, competitors, investors, universities, partners, government, pers.network, consultants, family, develop, access, priv-knowl., phys-struct., cash}, {prod./svc.}, {market}

Q-Table 1: Biotech: All firms

q-level	Q	Q*	Equivalence Classes
41	1	0	{develop}
30	2	1	{customers}, {develop}
25	2	1	{employees}, {customers, develop}
24	1	0	{employees, customers, develop}
20	2	1	{firm, employees, customers, develop}, {prod./svc.}
18	3	2	{firm, employees, customers, develop}, {access}, {prod./svc.}
14	4	3	{firm, employees, customers, develop}, {access}, {prod./svc.}, {cash}
13	5	4	{firm, employees, customers, develop}, {investors}, {access}, {prod./svc.}, {cash}
12	4	3	{firm, employees, customers, develop}, {investors}, {access, cash}, {prod./svc.}
9	4	3	{firm, employees, customers, competitors, develop}, {investors}, {access, cash}, {prod./svc.}
7	4	3	{firm, employees, customers, competitors, universities, develop}, {investors, access}, {prod./svc.}, {cash}
6	4	3	{firm, employees, customers, competitors, investors, universities, develop}, {government}, {access, cash},
5	3	2	{firm, employees, customers, suppliers, competitors, investors, universities, government, develop, access}, {prod./svc.}, {cash}
4	3	2	{firm, employees, customers, suppliers, competitors, investors, universities, partners, government, develop, access, phys-struct.}, {prod./svc.}, {cash, market}
3	3	2	{firm, employees, customers, suppliers, competitors, investors, universities, partners, government, pers.network, develop, access, phys-struct.}, {prod./svc.}, {cash, market}
2	3	2	{firm, employees, customers, suppliers, competitors, investors, universities, partners, government, pers.network, family, develop, access, priv-opinion, phys-struct.}, {prod./svc.}, {cash, market}
1	3	2	{firm, employees, customers, suppliers, competitors, investors, universities, partners, government, pers.network, family, develop, access, priv-opinion, phys-struct., cash}, {prod./svc.}, {market}

Q-Table 2: New media: All firms

q-level	Q	Q*	Equivalence Classes
11	1	0	{develop}
5	3	2	{firm, employees, develop}, {investors}, {prod./svc.}
4	3	2	{firm, employees, investors, universities, develop}, {prod./svc.}, {cash}
3	3	2	{firm, employees, customers, investors, universities, develop}, {prod./svc.}, {cash}
2	3	2	{firm, employees, customers, investors, universities, consultants, develop}, {access, cash, market}, {prod./svc.}
1	3	2	{firm, employees, customers, suppliers, competitors, investors, universities, partners, consultants, develop, access, cash}, {prod./svc.}, {market}

Q-Table 3: Biotech: Top 3 firms

q-level	Q	Q*	Equivalence Classes
9	1	0	{develop}
7	1	0	{universities, develop}
5	2	1	{firm, employees, universities, develop}, {investors}
4	4	3	{firm, employees, universities, develop}, {investors}, {access}, {prod./svc.}
3	4	3	{firm, employees, universities, develop}, {investors, access}, {prod./svc.}, {cash}
2	3	2	{firm, employees, investors, universities, develop, priv-knowl.}, {access, cash}, {prod./svc.}
1	3	2	{firm, employees, customers, investors, universities, partners, consultants, develop, access, priv-knowl., phys-struct.}, {prod./svc.}, {cash, market}

Q-Table 4: Biotech: Bottom 3 firms

q-level	Q	Q*	Equivalence Classes
8	1	0	{develop}
6	2	1	{customers}, {develop}
5	1	0	{customers, develop}
4	2	1	{employees, customers, develop}, {prod./svc.}
3	2	1	{firm, employees, customers, competitors, develop}, {prod./svc.}
2	4	3	{firm, employees, customers, competitors, develop}, {investors}, {access, cash}, {prod./svc.}
1	3	2	{firm, employees, customers, suppliers, competitors, investors, develop}, {pers.network, access, cash}, {prod./svc.}

Q-Table 5: New media: Top 3 firms

q-level	Q	Q*	Equivalence Classes
8	1	0	{develop}
4	4	3	{firm, employees, develop}, {customers}, {investors}, {cash}
3	4	3	{firm, employees, customers, develop}, {investors, government}, {prod./svc.}, {cash}
2	3	2	{firm, employees, customers, investors, universities, government, develop}, {access, cash}, {prod./svc.}
1	3	2	{firm, employees, customers, competitors, investors, universities, government, develop, access, cash}, {prod./svc.}, {market}

Q-Table 6: New media: Bottom 3 firms

Appendix 2: Q-Chains

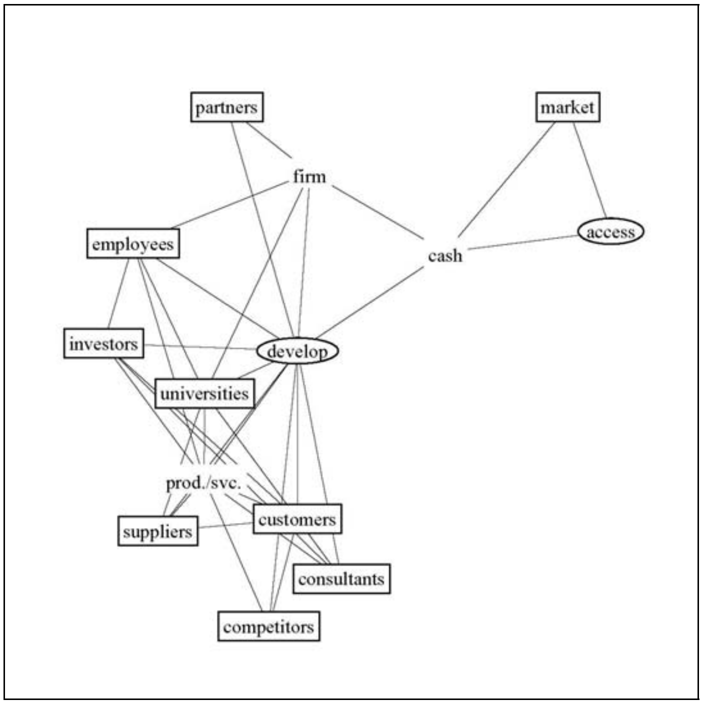

Figure 2: Q-Chain: Top 3 biotech firms at q-level = 1

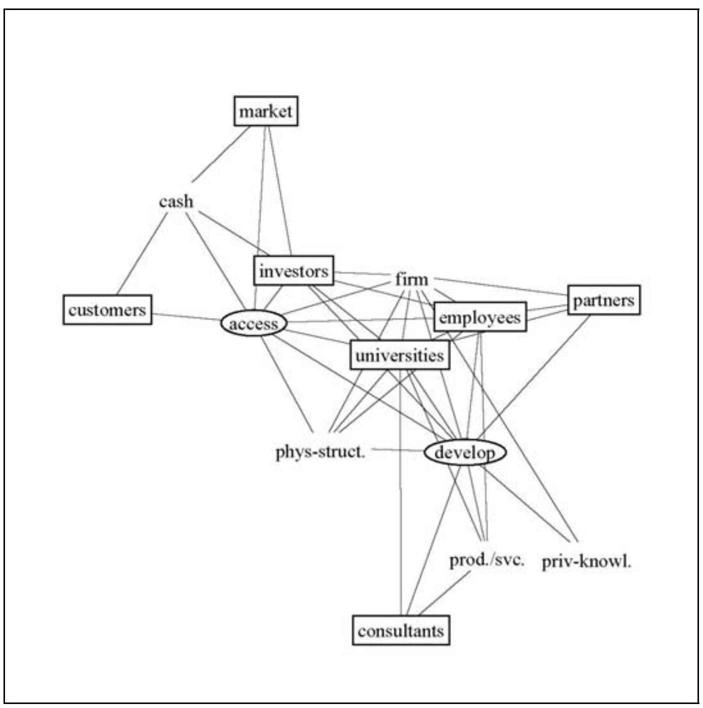

Figure 3: Q-Chain: Bottom 3 biotech firms at q-level = 1

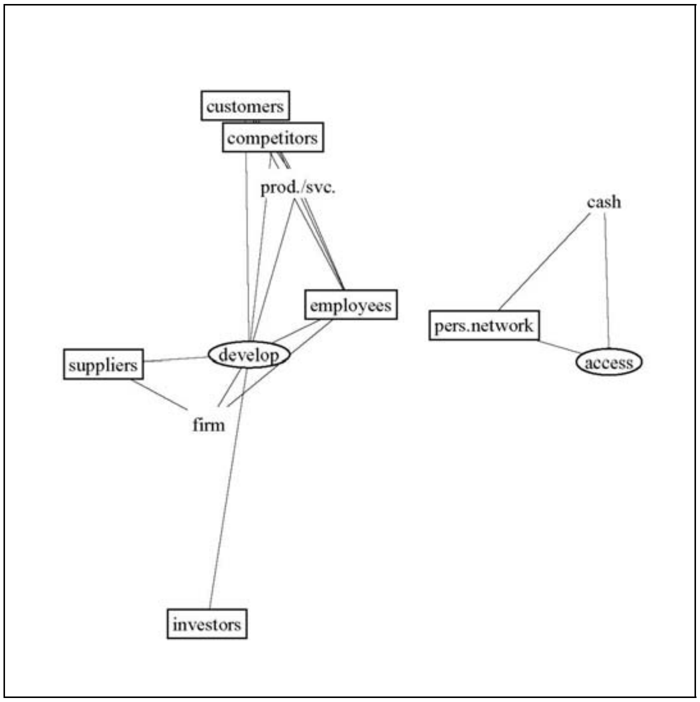

Figure 4: Q-Chain: Top 3 New media firms at q-level = 1

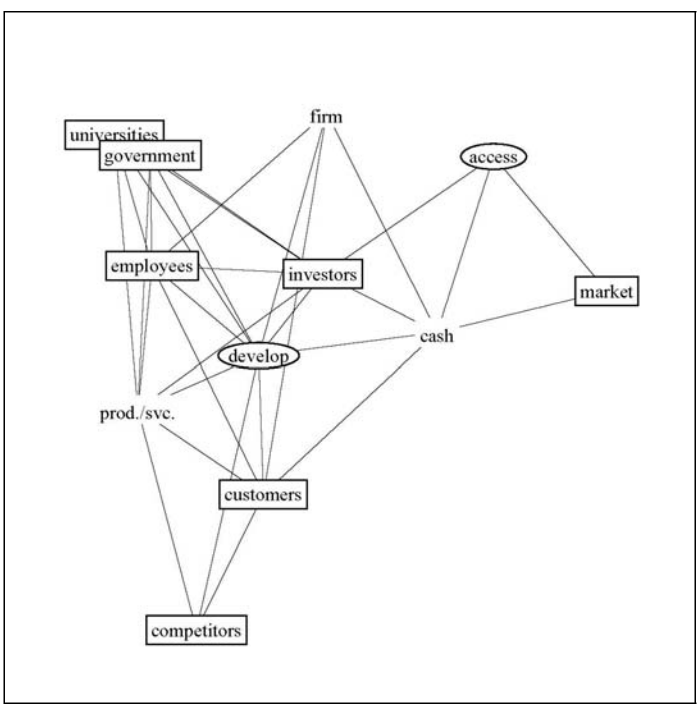

Figure 5: Q-Chain: Bottom 3 New media firms at q-level = 1