Network Externalities in Corporate Financial Management

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1. Background and Motivation

In a world where change is the only reliable constant, the organizational form of networks becomes increasingly more significant for institutions adapting to their changing environment. The nonlinear interactions influence strategic management decisions and affect the corporate performance. Although networks are vital intangible assets and their dynamics are vital sources of risk, the finance literature either ignores their complex properties or approximates them with simple linear heuristics. The predominant network externalities with particular relevance to corporate valuation are network growth and network resilience. [Albert, Jeong, and Barabasi 2000; Callaway, Newman, Strogatz, and Watts 2000; Cohen, Erez, ben-Avraham, and Havlin 2000]

The explanation for this discrepancy is that network externalities are extremely difficult to internalize into decisions, due to their unintuitive nature. Instead the risk is addressed on a different scale of aggregation in areas such as supply chain management, customer relationship management, key account management, or investor relationship management. In consequence, managers face a multitude of contrary advices as the increasing complexity leads to vast deviations between the cognitively constrained expectations of managers and the real-world developments. In this setting the key to successful network management is to understand the underlying network properties and dynamics on different scales of observation and to internalize them in the corporate decision-making process. Without being aware of these implications and a systematic approach, it is strenuous, if not impossible, to comprehend, to predict, or to manage the nonlinear risks and benefits of networks.

A promising perspective which has sparked a growing movement to bolster management is the increasing body of research on complex systems. The research purpose of this paper is to investigate the potential implications of an internalization of network externalities for the financial literature. Therefore, the article contains five sections. In a first step, the nature of the network phenomenon is outlined from a complex systems perspective. Based on this framework, we formulate a network theoretical research approach to network growth and network resilience. In the main part of the paper, this methodology is applied to illustrative case studies in order to derive implications for shareholder value management. The article concludes with a summary of the research findings and an outlook on the further research agenda.

2. The Nonlinear Nature of Networks

The nonlinear nature of networks is one of the elementary building blocks of complexity [Newman 2003a]. Within complex systems theory, a variety of interdisciplinary theories contributes to the understanding of nonlinear characteristics and dynamics of complex systems, such as networks [Bar-Yam 1997]. Networks are interpreted as a conceptual entity consisting of interlinked subunits which cause complexity [Simon 1962]. The complexity of a system is a derivative of dynamic feedback loops. These feedback loops cause the network to behave nonlinearly. This complex behavior implied that small changes in one or more parameters can fundamentally change the behavior of the total system due to emerging properties that arise on various scales of observation [Casti 1994]. The respective switching between two performance modes occurs at critical values and can be interpreted in a thermodynamic analogy as a phase transition [Bar-Yam 1997]. Applied to management science, these insights require managers to analyze social systems with respect to "tipping points" as catalysts of such nonlinear phenomena, as they can have a substantial influence on decisions.

3. Network Description and Analysis

Appropriate tools from network theory are required for the description and analysis of networks. The basis for this perspective is the social network paradigm stating that societal phenomena share an underlying relational network structure [Wasserman and Faust 1994] which can be analyzed with graph theory [Harary 1995]. As a derivative of this research, the modern network analysis comprises structural and locational network theory as well as the dynamic network analysis [Burt 1982; Knoke and Kuklinski 1982; Scott 1992; Galaskiewiecz and Wasserman 1993; Wasserman and Faust 1994; Newman 2003a]

3.1 Structural and Locational Properties of Complex Networks

Structural and locational properties of networks are building blocks of more complex measures. The clustering coefficient is a basic measure for the network resilience, as it quantifies the transitivity and can be interpreted as the density of the network at that vertex [Fronczak, Holyst, Jedynak, and Sienkiewicz 2002]. Network research illustrates that the mean path lengths of networks increase more or less rapidly depending on the network configuration, on the transitivity of the removed vertex, and on the removal method of vertices. [Newman 2003a] Respective nonlinearities in networks can be detected if the local density is compared to the average density of the network. Additional information on the resilience of networks can be derived from the betweenness centrality of vertices, since it reveals how many geodesic paths become longer in a comparative analysis of the geodesic paths before and after the removal of a vertex [Wasserman and Faust 1994; Newman 2001]. Another measure for the robustness of a network is the differential between the average network mean distance before and after the removal of a vertex [Latora and Marchiori 2001]. A related network tool is the small-world concept which allows the analysis of the structural efficiency of networks [Milgram 1967; Watts 1999]. In short, a small-world network is a cliquish network, in which any network member can be reached through relatively few steps, because of a few short-cuts that exponentially decrease the average path lengths. Once the normalized network measures, the average path lengths, and the cluster coefficient are calculated, the small-world characteristics of a system can be analyzed and compared to data from other small-world networks [Buchanan 2002].

3.2 Dynamic Network Analysis of Complex Networks

While the previously outlined research tools are designed to explore the structural and the locational properties of networks, the preferential attachment model, the percolation theory, and epidemiology are the most promising methodologies in the analysis of the network dynamics [Barabási and Albert 1999; Barabási, Albert, and Jeong 1999; Dorogovtsev and Mendes 2002]. The percolation theory studies the behavior of a network by selecting at random edges and vertices for different state variables [Stanley 1983]. Central to this model is the analogy to the conduct of electric flows in electronic circuits in which the long-range connectivity of a network disappears below a critical threshold if edges are randomly deleted [Schwartz, Cohen, ben-Avraham]. The site percolation model is applied in network theory for the description of growths and resilience of networks, since it enables the calculation of the size differential of the largest component after the random deletion of an edge. In some networks, solely a fraction of the overall network has to be removed before the giant component is disintegrated and the total network performance is significantly diminished [Albert, Jeong and Barabási 2000]. On the other hand, it is also possible to determine the required percentage of relationships that has to be liquidated for destroying the giant component. [Dorogovtsev and Mendes 2001]. In this context the cascading failure model is another insightful expansion of the basic percolation model which illustrates that the failure of a single vertex affects other vertices and can even result in the total collapse of the network [Watts 2002].

Epidemiology is a second source of inspiration in the study of network dynamics. It is primarily concerned with the diffusion of information, resources, and diseases on network infrastructures [Newman, Forrest, and Balthrop 2002; Klovdahl, Potterat, Woodhouse, Muth, Muth and Darrow 1994]. Depending on the complexity of the underlying assumptions and on the desired precision, a broad spectrum of epidemiological endemic and epidemic models can be formulated. A basic model describing the propagation of epidemic contagious diseases in social networks is the SIR model [Hethcote 2000]. Depending on the parameter settings the characteristic dynamics of the disease can be determined by simultaneously solving the respective differential equations with a mean-field approximation [Barabási, Albert, and Jeong 1999; Pastor-Satorras and Vespignani 2001]. These insights from epidemiology can be transferred to networks by assuming a bond percolation process [Grassberger 1983]. According to this analogy, the percolation transition is equivalent to the epidemic threshold that has to be passed for an epidemic outbreak. The final number of infected vertices can be approximated as the size of the giant component [Callaway, Newman, Strogatz, and Watts 2000]. Whereas this analytical solution of the model derives the final equilibrium outcome of the disease, its dynamic behavior in the network can be observed with numerical simulations.

4. Network Externalities in Corporate Finance

Corporate risk management and investment valuation are vital instruments in corporate finance for achieving an optimal allocation of resources according to the primacy of shareholder value management [Copeland, Koller, and Murrin 1994]. Standard typologies in corporate risk management differentiate the overall risk of a corporation in business risk, event risk and financial market risk [Clarke and Varma 1999]. Since the dynamics of corporate networks depend systematically on the management's actions and are not solely a result of exogenous effects, the resulting relational risk is rather a business risk than an event risk. Therefore, networks threatening the infrastructure of corporate transactions play a vital role in the decision making and should be modeled appropriately. This observation holds also true for investment valuation, where the broad spectrum of parallel methodologies shares an implicit and static treatment of network externalities [Brealey and Myers 1990]. In consequence of the outlined nonlinear character of networks, small differences in initial conditions may give rise to extremely different path developments in valuations and risk assessments. This great sensitivity has to be addressed in the derivation of all input parameters with the appropriate network methodology. In order to investigate the significance of the assumptions concerning the effects of network externalities in a value-based decision-making framework, two clinical case studies are analyzed from the outlined network perspective.

4.1 Network Resilience in Corporate Finance

On February 2, 2002, the CEO of the Deutsche Bank gave an interview in a news channel in which he commented on the financial situation of Kirch Media. At that time, the German media conglomerate was in financial turmoil and negotiated its restructuring process with a pool of banks, since huge bank loans and an enormous individual claim threatened the financial integrity. In April 2002, these negotiations failed and the conglomerate collapsed with liabilities of almost two billion Euros. The group's CEO stated that the conditions of the negotiations with the banks had changed dramatically after the interview, whereas the CEO of the bank rejected allegations that he had triggered the collapse. Finally, a court ruled that the bank and its CEO were liable for damages by breaching client confidentiality and by publicly voicing doubts over the creditworthiness of the corporation. In December 2003, the revision of this case confirmed the verdict of the first instance and the bank now faces claims of damages in the amount of 6 billion Euros.

This case illustrates that the network resilience of financial networks is a central research object relevant to corporate finance. From a network theoretical perspective, the break-down of the banking support can be interpreted as a cascading network failure. The interview of the CEO is an excellent example of a targeted attack on the financial network, since his the announcement to stop the financial support liquidated one of the main vertices in the financial support network. Particularly, since the bank was one of the main creditors and the CEO is the president of the National Banking Committee, the interview initiated self-reinforcing financial pressure. This targeted attack on an essential vertex of the financial network destabilized its integrity and contributed to the final collapse. A reasonable approach to investigate the financial network integrity and its sensitivity to attacks consists in measuring the density of the financial network. The higher the density of the network, the less urgent is the need for risk management. Complementarily, the small-world properties of the financial network provide insights in the optimal configuration of the corporate network portfolio. A power-law is the best distribution of strong and weak ties in a trade-off relationship, as it is constrained by limited resources for building and maintaining network relationships.

As an implication of this network analysis, efficient relational risk management strategies can be designed. In this context, the real option perspective is a promising financial approach, to internalize network externalities in management bases on quantified insights from network theory [Trigeorgis 1996]. First, the corporation has the option of a multiplex strategy by adding several edges to the same vertex. From a real options perspective such an amplification of the existing relationship can be interpreted as a relational insurance option. Although this option is costly, since it requires resources for developing a greater level of cooperation, it contains at the same time a considerable amount of value, as the overall stability of the financial network is enhanced by the increase in the carrying capacity of vital vertices. Alternatively, the management could manage the relational risk with a structural equivalence strategy by searching for substitute vertex relationships. These substitutes may also require some investments, but offer the flexibility to exercise a switching option by exchanging one relationship in the network for another.

4.2 Network Growth in Corporate Finance

The second case study roots back to December 2002, when the Paybox.net AG, a German m-commerce firm, dismissed nearly 200 of the 240 employees after a series of financial negotiations with Deutsche Bank, its main investor. Prior to this development, the corporation had introduced the world's first mass-marketable mobile phone payment method in Germany and had expanded it rapidly as an own brand on European markets. Within a few months, the system became the world-wide leading m-payment method with respect to both users and acceptance points. However, the attempt to establish the technology as an international standard for convenient and secure mobile payment methods became increasingly difficult with the collapse of the financial markets in mid 2000. While from the firm's point of view both pillars of the income stream, the customer as well as the merchant business, were still expanding at satisfactory growth levels, the expansion speed no longer satisfied the bank. The financial contracting failed and the corporation was forced to change its business model to licensing its services to large third-party corporations.

In this case, the determination of a required critical mass of customers was the central problem in the negotiations, since both parties failed to agree on a common rational mechanism for the assessment of the required growth. The corporation required funding for the diffusion of a communication network innovation and, therefore, had to rationalize the financing of the underlying business model. A generic problem of all investment valuation approaches are the extremely vague estimations of its expected cash flows as the vital input of the models, since these depend on the sales projections. These, in turn are traditionally based on heuristic assumptions about the underlying customer network. In valuation practice, the sales projections are linearly adjusted approximations of the historical corporate performance. However, since the customer network complies to complex network dynamics, even tiny differentials between the assumptions and reality can have vast implications on the financial analysis. Obviously, an explicit treatment of the network externalities is necessary.

Interpreted from a network theoretical perspective, the assessment of the customer network is at the heart of the dilemma in financial contracting. Profitable business operation requires a critical mass of customers, as shareholders expect a positive contribution margin in the short run and a risk-compensating return above the initial investments in the long run. In the m-commerce case, mouth-to-mouth marketing drives the positive feedback dynamics that reinforce the distribution of the product and contribute to successful business operations once the critical barrier has been crossed. If, in contrast, the corporation is not capable to pass the transition boundary, rebalancing feedback dynamics drive the product innovation out of the market. In terms of network theory, the size of the giant component has to cross a critical value in order to stabilize the profitability of the diffusing product. Therefore, both contracting parties have to agree on a common model for the quantification of the customer network. Thereby, it is possible to determine the phase transition boundary, to assess the probabilities for crossing it, and to derive the final customer network sizes. Once the distribution of likely network sizes is determined for different parameter regimes, the expected distribution of cash flow, and thereby the value of the corporation can be derived.

As an implication from the network research, the application of the SIR model is one way to design a network solution to the outlined problem. In a first step, the set of all potential customers is interpreted as a customer network and the parameters of the model are derived from empirical statistics. In analogy, the infection rate represents the probability that a customer purchases a product because of an infection from a network neighbor. The degree of susceptibility is affected by the marketing strategy, the need for the product, and other market parameters. The recovery rate is equal to the sum of the effects that might lead to an end of the consumption, e.g. force of substitution, competition, and others. Finally, analytical solutions and numerical simulations can be applied in order to determine the equilibrium amount of customers in the customer network. As outlined previously, an analytical methodology for solving this problem is the mean-field theory assuming that the influence on the consumption decision of an individual is equal to the average effect of all short-range neighbors. Depending on the configuration of the resulting network model, the simulations exhibit continuous network sizes in the final state. In combination with the empirically rationalized turnover per customer, expectations can be formulated concerning the overall revenues of the customer network. Once the revenues of the assessed investment are rationally approximated, the network effects on other vital valuation input parameters have to be assessed in the derivation of the underlying cash flows of the corporation. If the model parameters are varied within the most realistic regimes, it is possible to calculate the distribution of the investment cash flows for different scenarios around the mean and the corresponding volatility. The vital added value of the internalization of network externalities is the extraction of additional information on the structural network properties in the calculation of the expected customer size, the corresponding revenues, and other vital input parameters.

5. Summary and Outlook

In essence, the assessment of the case studies reveals that the nonlinearity of networks is vitally influencing the risk and the value of corporations, since the dynamics of information age companies are not smooth and linear, but rather disruptive and nonlinear. While in the m-commerce case the growth of networks is the central phenomenon, in the case of the media conglomerate, the resilience of the financial network is of vital importance. The m-commerce case demonstrates the necessity for research on network growth in order to rationalize management decisions, since it is difficult to comprehend without an understanding of the underlying network dynamics. In contrast, once a critical mass required for financially stable business is quantified, the respective financing decisions can be rationalized, as investments in such prospective projects can be valued appropriately. Complementarily, the case of the media conglomerate illustrates the importance of network resilience and network integrity as corporations exist in a business environment and depend crucially on the underlying transaction network infrastructure. In both cases, the understanding of the underlying network externalities according to shareholder value principles is a critical success factor in the financial negotiations. Thereby, the case studies emphasize the necessity for an internalization of network growths and network resilience as vital externalities in corporate financial decision-making. The proposed internalization of the network externalities with the graph theory establishes a link between network analysis, corporate finance, and strategic business development. Furthermore, it emphasizes the necessity for financial research on the design of optimal network management strategies and the benefits of a general diffusion of the underlying complex systems principles in management.

This article is a first roadmap to a variety of unanswered research questions which result from a complex systems perspective on financial management. Additional quantitative investigations of the analyzed case studies is likely to enhance the mediation of financial contracting problems. However, the appropriate relational data and the respective computer programs are required in order to test the network strategies empirically. In addition, the large size of real-life networks and computational problems are further research obstacles. All these research activities have the potential to increase the popularity of the outlined ideas among managers and contribute to a broader diffusion of the underlying complex systems principles in management.

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