Modelling the Dynamics of Relations and Networks in B2B Markets - First Steps of a Research Project

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Abstract

The dynamics and evolution of relations and networks in B2B markets has received limited research attention. However they are important in developing appropriate strategies for relationship and network participation and management. One way to advance our understanding is through agent-based simulation models that are now being developed to explore dynamics and evolutionary processes in a number of disciplines. We identify the main mechanisms driving the evolution of business relations and networks and review models from various disciplines that attempt to represent these. This will provide the basis for developing our models and also identifies where additional modelling efforts are required.

Keywords: business relations, networks, mechanisms, dynamics, evolution, agent-based models

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Introduction

Existing research and theory regarding the dynamics and evolution of relations and networks in B2B markets is limited. However understanding the way relations and networks develop and evolve is critical in developing appropriate strategies for relationship and network participation, management and regulation. Relations and networks are not static they are continuously being made and remade as a result of the experience and outcomes of the interactions taking place.

Most research is comparative static in nature, based on cross-sectional surveys of business relations. The exceptions to this are: stage models that assume a pre-given sequence of stages with each stage providing the preconditions for the next (e.g. Dwyer, Schurr and Oh, 1987; Ford, 1980); case studies and descriptions of relationship and network histories (e.g. Kinch, 1993; Welch and Wilkinson, 2002); and theories about the mechanisms driving the dynamics of relations and networks (e.g. Håkansson and Snehota, 1995; Halinen and Törnroos, 1998; Huang and Wilkinson, 2006; Wilkinson, 1990).

One way of advancing research is through the use of computer simulations, especially agent-based methodologies, which are becoming ever more widely used and appreciated. Their use is becoming more frequent in the social sciences generally (Gilbert and Troitzsch, 2005), including marketing (Midgley, Marks and Cooper, 1997; Watts and Dodds, 2007) and economics (Tesfatsion and Judd, 2006). Even specialized journals are emerging such as the online *Journal of Artificial Societies and Social Simulation*. The uses of computer simulation are manyfold with Axelrod (2006), for example, listing seven: prediction, performing tasks, training, entertaining, educating, existence proofs and discovery. For scientific research, the main goals are prediction, existence proofs and discovery.

An example of successful discovery through simulation is by Watts and Dodds (2007), who challenge theories about the importance of critical individuals (opinion leaders) in diffusion processes. Their simulations suggest that under most conditions large cascades of diffusion are driven not by influentials but by a critical mass of easily influenced individuals. In training and education, simulations have the potential to present abstract theories in a visually appealing and engaging way, e.g. a simulation of the "Beer Game" can give manager and business students a feel for the many interdependencies in supply chains (Holweg and Bicheno, 2002) and agent-based models lie behind most of the online and computer games that have become popular, such as Second Life, Simlife, SimCity and The Sims. Along similar lines, "flight simulators" can be developed to allow managers and policy makers to experiment with alternative strategies in complex systems that are beyond analytical solutions, individual control and simple rules of thumb.

Some simulation models have been developed that capture certain aspects of business network dynamics. For example simulations have used Boolean rules to represent the way exchanges are connected (e.g. Easton, Wilkinson and Georgieva, 1997; Easton et al. 2008; Wilkinson, Wiley and Easton, 1999) and to represent aspects of the evolution of a particular industry (e.g. Følgesvold and Prenkert, 2009). But no attempts have been made to develop more comprehensive simulation models that can be calibrated and tested against the dynamics and known histories of real relations and networks.

The kind of explanation sought here is different from variance based approaches that seek to reproduce the patterns of correlations among variables. Our concern here is to reproduce patterns and processes of change in the sense of Herbert Simon: "to 'explain' an empirical regularity is to discover a set of simple mechanisms that would produce the former in any system governed by the later" (Augier and March, 2004, p.5). Or, as Epstein (2006) argues - to grow (or generate) is to explain.

The purpose of this paper is to identify the main mechanisms and processes that simulation models of the development of business relations and networks need to include if they are to be meaningful and useful and to consider the extent to which existing models provide ways of modelling them. In the next section we identify the main types of mechanisms driving relation and network dynamics and evolution. Next, we discuss and illustrate how each of these have been modelled in previous simulations and identify areas requiring more research. We conclude by describing a program of research designed to develop and test agent-based models of the dynamics and evolution of business relations and networks.

Mechanisms of Business Relationship and Network Formation and Development

In order to develop meaningful and useful simulation models of business networks we need to understand the underlying causal mechanisms driving their dynamics and evolution, and how they may be incorporated into simulation models. Mechanisms have to do with how something has an effect; the actual processes that are involved in one thing leading to another.

> "Mechanisms [...] consist of *entities* (with their properties) and the *activities* that these entities engage in, either by themselves or in concert with other entities [...] a constellation of entities and activities that are organized such that they regularly bring about a particular type of outcome." (Hedström, 2005, p.25)

Based on prior research we have identified five basic types of mechanisms driving the dynamics business relations and networks. These mechanisms cover the formation of relationships, what happens in them as they evolve over time, how they end as well as how different relationships affect each other, and how the environment can have an effect on their development. The categorization is chosen to capture the most important mechanisms which explain the development of business relations and networks in a logically complete framework.

First, there are mechanisms that affect the way firms specialise in different activities. These depend on the effects of economies of scale and scope operating in the performance of different activities and the transactions costs involved. Individual firms face make-or-buy decisions that involve a trade-off between the economies available internally in performing activities and the transaction costs of linking and coordinating with other specialist firms. Operating and transaction costs are both subject to scale and scope efficiencies that depend on characteristics of the technology, market size , the type of relation and the characteristics of the transactions involved (Williamson, 1981).

There is also an interaction between economies of specialization and competition. Intermediaries reduce the number of transactions and make each one bulkier, realizing efficiencies unattainable to individual buyers or sellers. However, a single intermediary is a type of monopolist who may be able to realize supernormal profits, which would attract new intermediaries to set up. The number of intermediaries that can enter a market is limited by

cost structures, market size, the number of buyers and sellers and the way they allocate their business (Balderston, 1958).

Second, there are mechanisms concerning the way firms establish relations with each other, what has been described as business mating (Wilkinson, Young and Freytag, 2005). People as well as firms tend to form relations with those they have dealt with in the past, those that are operationally similar and those offering complementary resources. Once a partner is found negotiation begins and different forms of governance are established, affected by the costs associated with adaptation, performance evaluation and safeguarding (Rindfleisch and Heide, 1997). Governance structures range from arm's length market trading through cooperative relations to hierarchical governance (ownership).

Third, once the terms of cooperation are settled the relationship evolves over time, based on the experience and outcomes of economic and social interactions. Firms learn about each other and make investments in terms of time, effort and money. There are ongoing adaptations of resources, activities, schemas and bonds resulting in the development of a "relationship atmosphere" between the actors involved (Håkansson, 1982). The way the relation develops and the specificity of the investments and adaptations required affects switching costs, what can lead to lock-in effects and increases the potential of damage from opportunism (Williamson, 1975).

Fourth, relations are interconnected in various ways, such that activities and outcomes in one can affect others (Anderson, Håkansson and Johanson, 1994). Also a firm's actions and performance depend on the portfolio of relations it is involved in rather than individual relations. Interdependencies affect the total demand for a firm's outputs, the costs involved and the way knowledge and ideas move around networks. Relations and interactions can be interconnected vertically as stages in supply chains, in competing and complementary relations and in reciprocal relations (Bergen, Dutta and Walker Jr, 1992; Turnbull, David and Malcolm, 1996). The emergence and use of intermediaries also leads to the development of sequences of connected relations instead direct relations between buyers and sellers.

Lastly, relations operate in the context of various types of broader physical, technological and socio-economic systems that affect how they behave and develop in various ways. Physical distance affects interactions. Market size constrains the degree of specialisation and number of intermediaries that can develop. Technology affects the nature and impact of scale and scope economies and how interconnected activities are. Firms respond to changes in technology, markets and regulations and to competitive conditions with different speeds and strategies. The characteristics of goods and services shape operating and transaction costs, including replacement rates, gross margins, customization, durability, and search time.

Modelling Mechanisms

Many mathematical and simulation models have been proposed that use mechanisms similar to the ones outlined above. In some cases these were built to capture business processes (Tesfatsion, 1997), while in other cases they come from domains such as biology (Seufert and Schweitzer, 2007) or sociology (Pujol, *et al.*, 2005). Most of this research addresses complexity and the phenomenon of self-organization in complex adaptive systems. As such business networks are a special case of these systems so that we can draw on the results from more general research in this domain. We have undertaken a review of such models which is

too extensive to describe fully here. In the following we illustrate some of the ways various mechanisms may be modelled.

Computer simulations can be initiated in terms of actors with different characteristics, roles and degrees of specialisation, but modelling the processes by which these differences emerge and develop over time is not so well developed. One exception is the BankNet model (Sapienza, 2000) that allows specialized banking intermediaries to emerge. Agents gain experience through successful interactions, more experienced agents are automatically more successful in their investments, what makes them more attractive for depositors. Thus they grow and reduce their marginal transaction costs through economies of scale. The emergence of innovation networks is observed in Gilbert, Pyka and Ahrweiler (2001). Striving for innovations, agents have the options to work independently, imitate, or coordinate research strategies in collaborations or networks. Agents can specialize, concentrating their research expertise on selected areas.

The literature on partner search and mating mechanisms in simulations is abundant, as it is one of the core mechanisms necessary to design a network simulation. Simple models of network generation use random pairing (Erdös and Renyi, 1959) or preferential attachment relative to the number of existing links (Barabási and Albert, 1999). Preferential attachment has been extended in many ways. Agents might lose attractiveness with age (Dorogovtsev and Mendes, 2000), or form relationships relative to activity (Fan and Chen, 2004), or performance (Ren*, et al.*, 2006) or based on prior successful cooperation (Gilbert, Pyka and Ahrweiler, 2001). Relationships can also be formed depending on expectations (Tesfatsion, 1997), or by copying links of established members (Vázquez, 2000).

Business dancing, the way firms interact, learn and adapt relations over time (Wilkinson and Young, 1994), has been dealt with in terms of various types of learning models and in terms of iterated game theory. Learning has been modelled in a number of ways in simulations to reflect the ways people and firms adapt their perceptions of each other and how this affects their behaviour. These include changes in trust, power and cooperation (Kim, 2009; Tomassini, Pestelacci and Luthi, 2010). Axelrod and Hamilton's (1981) early simulations focused on the iterated prisoner's dilemma and the conditions under which cooperative strategies emerge. Later work has considered other types of games and the evolution of strategies as a result of the experience of and performance in interactions over time. If agents in networked games have the capability to terminate unsatisfactory relationships, high levels of cooperation can be attained (Zimmermann, Eguíluz and San Miguel, 2004). Selective linking and alignment of each other's characteristics can lead to homogeneous neighbourhoods and a network structure with small-world characteristics (Gong and Leeuwen, 2004). In a simulation of the Marseille's fish market, buying and selling agents learn to engage in and reward loyal behaviour. Sellers can reduce their risk caused by demand volatility and buyers benefit from better service and discounts (Kirman and Vriend, 2001).

Many simulations depict the way relations are interconnected in terms of the effects of network structure on activities performed, including impacts on learning strategies and the profits of traders (Ladley and Bullock, 2008). Cooperative behaviour in strategic games is facilitated if networks are sparsely connected (Ohtsuki*, et al.*, 2006). Preferential attachment tends to connect hubs with each other and it has been found that cooperation can spread from such a cluster to the entire network (Santos and Pacheco, 2005). Network positions can affect individual payoffs (Wilhite, 2006) and the establishment of trust and reliability in one relationship can impede the success of another (Kim, 2009). Networks for economic interactions and those for the exchange of information do not necessarily coincide.

Lastly, the impact of the environment can be seen from an applied or a technical perspective. Testing the implications of taxes and subsidies, showed that they can facilitate the establishment of cooperative behaviour, which proved to be persistent, even after these were terminated (Lugo and Jiménez, 2006). More technical results show that the network structure is influenced by the payoffs of strategic games as well as the reliability of communication transmission (Pujol*, et al.*, 2005). Also, the relation between the time scales of actions on the network and the speed of the rewiring process of the network has been found to be important. A high rewiring speed of connections can essentially change the payoff structure of strategic games so that they favour cooperation (Pacheco, Traulsen and Nowak, 2006)

Discussion and Conclusions

This paper has reviewed literature in economics and marketing to identify key mechanisms affecting the dynamics and evolution of business networks. We have grouped them logically as mechanisms of specialization and division of labour, business mating, business dancing, connections between relationships and environmental impacts. Contrasting these mechanisms with implementations in network simulations yields interesting insights. While examples for each basic type are available, the congruence with empirically identified mechanisms is limited and requires further model development in order to represent them. Only few examples could be found for the development of specialization in simulations. Many simulations deal with search mechanisms and their impact on network topologies that mimic empirical processes. Nevertheless, there seem to be no simulations allowing agents to negotiate the terms of a relationship. Simulations do not yet capture the richness and multidimensional nature of the evolution of relationships. In most simulations a connection either exists, or not. Only Kirman and Vriend (2001) can be seen as an exception here. Simulations represent interconnected relationships in terms of overall network topology and positions rather than in terms of the types of connections identified in marketing theory (e.g. Anderson, Håkansson, and Johanson, 1994). Environmental impacts in terms of the heterogeneity or location of actors have not yet been included in simulations. Including such heterogeneity allows a closer matching of simulations with actual business networks but necessarily restrict the generality of simulations. There is also a need to develop simulations that reflect the mechanisms by which heterogeneity and location of actors arises endogenously and changes over time.

We are currently engaged in a research program to build dynamic evolutionary models of business networks, starting with separate models of basic mechanisms. We plan to demonstrate some of these as part of the presentation of this paper. These will form the basis of more comprehensive models that will be built in a modular manner in order to monitor the impact of different mechanisms, their representation and the way they interact. The models will be calibrated and tested against the results of studies of actual business relations and networks, including the way variables measuring different dimensions of business relations co-vary. In this way we are able to link our models with existing variance based research.

References

Anderson, J.C., Håkansson, H., Johanson, J., 1994. Dyadic Business Relationships within a Business Network Context. Journal of Marketing 58 (4), 1-15.

Augier, M., March, J.G., 2004. Models of a Man: Essays in Memory of Herbert A. Simon, The MIT Press, Cambridge, Massachusetts.

Axelrod, R., 2006. Simulation in the Social Sciences. In: Rennard, J.-P., (Ed.) Handbook on Research on Nature-Inspired Computing for Economics and Management. Idea Group, Hershey PA, 90-100.

Axelrod, R., Hamilton, W.D., 1981. The Evolution of Cooperation. Science 211 (4489), 1390-1396.

Balderston, F.E., 1958. Communication Networks in Intermediate Markets. Management Science 3 156-171.

Barabási, A.-L., Albert, R., 1999. Emergence of Scaling in Random Networks. Science 286 (5439), 509-512.

Bergen, M., Dutta, S., Walker Jr, O.C., 1992. Agency Relationships in Marketing: A Review of the Implications and Applications of Agency and Related. Journal of Marketing 56 (3), 1-24.

Dorogovtsev, S., Mendes, J., 2000. Evolution of Networks with Aging of Sites. Physical Review E 62 (2), 1842-1845.

Dwyer, F.R., Schurr, P., Oh, S., 1987. Developing Buyer-Seller Relationships. Journal of Marketing 51 11-27.

Easton, G., Brooks, R.J., Georgieva, K., Wilkinson, I.F., 2008. Understanding the Dynamics of Industrial Networks Using Kauffman Boolean Networks. Advances in Complex Systems 11 (1), 139-164.

Easton, G., Wilkinson, I.F., Georgieva, C., 1997. Towards Evolutionary Models of Industrial Networks - a Research Programme. In: Gemünden, H.G., Ritter, T., Walter, A., (Eds.). Relationships and Networks in International Markets. Elsevier, Oxford, 273-293.

Epstein, J.M., 2006. Remarks on the Foundations of Agent-Based Generative Social Science. In: Tesfatsion, L., Judd, K.L., (Eds.). Handbook of Computational Economics. Elsevier, Amsterdam, 1585-1604.

Erdös, P., Renyi, A., 1959. On Random Graphs. Publ. Math. Debrecen 6 290-297.

Fan, Z., Chen, G., 2004. Evolving Networks Driven by Node Dynamics. International Journal of Modern Physics B 18 (17-19), 2540-2546.

Følgesvold, A., Prenkert, F., 2009. Magic Pelagic - an Agent-Based Simulation of 20 years of Emergent Value Accumulation in the North Atlantic Herring Exchange System. Industrial Marketing Management 38 (5), 529-540.

Ford, D., 1980. The Development of Buyer-Seller Relationships in Industrial Markets. European Journal of Marketing 15 (5/6), 339-354.

Gilbert, N., Pyka, A., Ahrweiler, P., 2001. Innovation Networks - a Simulation Approach. Journal of Artificial Societies and Social Simulation 4 (3),

Gilbert, N., Troitzsch, K.G., 2005. Simulation for the Social Scientist, Open University Press, Berkshire, UK.

Gong, P., Leeuwen, C.v., 2004. Evolution to a Small-World Network with Chaotic Units. EPL (Europhysics Letters) (2), 328.

Håkansson, H., 1982. International Marketing and Purchasing of Industrial Goods, Wiley, Chichester, UK.

Håkansson, H., Snehota, I., 1995. Developing Relationships in Business Networks, Routledge, London, UK.

Halinen, A., Törnroos, J.-Å., 1998. The Role of Embeddedness in the Evolution of Business Networks. Scandinavian Journal of Management 14 (3), 187-205.

Hedström, P., 2005. Dissecting the Social: On the Principles of Analytical Sociology Cambridge University Press, Cambridge, UK

Holweg, M., Bicheno, J., 2002. Supply Chain Simulation - a Tool for Education, Enhancement and Endeavour. International Journal of Production Economics 78 (2), 163-175.

Huang, Y., Wilkinson, I., 2006. Understanding Trust and Power in Business Relationships: A Dynamic Perspective. In International Marketing and Purchasing Group Conference. Università Commerciale Luigi Bocconi, Milan, Italy.

Kim, W.-S., 2009. Effects of a Trust Mechanism on Complex Adaptive Supply Networks: An Agent-Based Simulation Study. Journal of Artificial Societies and Social Simulation 12 (3), 4.

Kinch, N., 1993. The Long-Term Development of Supplier-Buyer Relation. In International Marketing and Purchasing Group Conference. Bath, UK.

Kirman, A.P., Vriend, N.J., 2001. Evolving Market Structure: An Ace Model of Price Dispersion and Loyalty. Journal of Economic Dynamics and Control 25 (3/4), 459-502.

Ladley, D., Bullock, S., 2008. The Strategic Exploitation of Limited Information and Opportunity in Networked Markets. Computational Economics 32 (3), 295-315.

Lugo, H., Jiménez, R., 2006. Incentives to Cooperate in Network Formation. Computational Economics 28 (1), 15-27.

Midgley, D.F., Marks, R.E., Cooper, L.G., 1997. Breeding Competitive Strategies. Management Science 43 (3), 257-275.

Ohtsuki, H., Hauert, C., Lieberman, E., Nowak, M.A., 2006. A Simple Rule for the Evolution of Cooperation on Graphs and Social Networks. Nature 441 502-505.

Pacheco, J.M., Traulsen, A., Nowak, M.A., 2006. Coevolution of Strategy and Structure in Complex Networks with Dynamical Linking. Physical Review Letters 97 (25), 258103-258104.

Pujol, J.M., Flache, A., Delgado, J., Sangüesa, R., 2005. How Can Social Networks Ever Become Complex? Modelling the Emergence of Complex Networks from Local Social Exchanges. Journal of Artificial Societies and Social Simulation 8 (4), 12.

Ren, J., Wu, X., Wang, W.X., Chen, G., Wang, B.H., 2006. Interplay between Evolutionary Game and Network Structure: The Coevolution of Social Net, Cooperation and Wealth. Arxiv preprint physics/0605250

Rindfleisch, A., Heide, J.B., 1997. Transaction Cost Analysis: Past, Present, and Future Applications. Journal of Marketing 61 (4), 30-54.

Santos, F.C., Pacheco, J.M., 2005. Scale-Free Networks Provide a Unifying Framework for the Emergence of Cooperation. Physical Review Letters 95 (9), 98104.

Sapienza, M.D., 2000. An Experimental Approach to the Study of Banking Intermediation: The Banknet Simulator. In: Luna, F., Stefansson, B., (Eds.). Economic Simulation in Swarm. Kluwer Academic Publishers, Boston, 159-179.

Seufert, A.M., Schweitzer, F., 2007. Aggregate Dynamics in an Evolutionary Network Model. International Journal of Modern Physics C 18 (10), 1659-1674.

Tesfatsion, L., 1997. A Trade Network Game with Endogenous Partner Selection. Computational approaches to economic problems 249-269.

Tesfatsion, L., Judd, K.L., 2006. Handbook of Computational Economics. In Handbooks in Economics. Elsevier, Amsterdam.

Tomassini, M., Pestelacci, E., Luthi, L., 2010. Mutual Trust and Cooperation in the Evolutionary Hawks-Doves Game. BioSystems 99 (1), 50-59.

Turnbull, P., David, F., Malcolm, C., 1996. Interaction, Relationships and Networks in Business Markets: An Evolving Perspective. Journal of Business and Industrial Marketing 11 (3), 44-62.

Vázquez, A., 2000. Knowing a Network by Walking on It: Emergence of Scaling. In arXiv:cond-mat/0006132v4.

Watts, D.J., Dodds, P.S., 2007. Influentials, Networks, and Public Opinion Formation. Journal of consumer research 34 (4), 441-458.

Welch, C., Wilkinson, I.F., 2002. Idea Logics and Network Theory in Business Marketing. Journal of Business-to-Business Marketing 8 (3), 27-48.

Wilhite, A., 2006. Economic Activity on Fixed Networks. In: Tesfatsion, L., Judd, K.L., (Eds.). Handbook of Computational Economics. Elsevier, 1013-1045.

Wilkinson, I., F., Young, L., 1994. Business Dancing: An Alternative Paradigm for Relationship Marketing. Australasian Marketing Journal 2 (1), 67-80.

Wilkinson, I.F., 1990. Toward a Theory of Structural Change and Evolution in Marketing Channels. Journal of Macromarketing 10 18-46.

Wilkinson, I.F., Wiley, J., Easton, G., 1999. Simulating Industrial Relationships with Evolutionary Models. In 28th European Marketing Academy Annual Conference. Humbold University, Berlin.

Wilkinson, I.F., Young, L., Freytag, P.V., 2005. Business Mating: Who Chooses and Who Gets Chosen? Industrial Marketing Management 34 (7), 669-680.

Williamson, O.E., 1975. Markets and Hierarchies: Analysis and Anti-Trust Implications, The Free Press, New York.

Williamson, O.E., 1981. The Modern Corporation: Origins, Evolution, Attributes. Journal of Economic Literature 16 1537-1568.

Zimmermann, M.G., Eguíluz, V.M., San Miguel, M., 2004. Coevolution of Dynamical States and Interactions in Dynamic Networks. Physical Review E 69 (6), 065102.