How abstract mechanisms come alive: modelling network path dependence with qualitative data.

Frithjof Stöppler[1[0000-0002-4124-4189]]

[1] Stockholm University, Postbox 7003, SE-164 07 Kista, Sweden
frithjof@dsv.su.se

Abstract. Modelling conceptually abstract social mechanisms generally raises questions of empirical and ontological correspondence. Modelling (path dependent) dynamics of interorganisational networks is thus challenging. The inability to observe certain empirical phenomena while unfolding and the additional lack of readily available mathematical network measure data requires a new empirical approach. I report on how I conducted a qualitative case study of two embedded cases in the smartphone industry using a diversity of data sources for grounding a theory-driven simulation model. Subsequently, I explain how these empirical foundations affected model implementation and key results, and I conclude with a reflection on how qualitative case studies can help underpin the simulation of emergent network dynamics.

Keywords: ABM, path dependence, interorganizational networks, case study, qualitative data.

1 Introduction & Background

1.1 Research interest

Organisations rely on productive relationships with other organisations to pursue their diverse objectives. Such connections have been characterised as ‘interorganisational networks’ when the interrelations exceed the most basic, dyadic level [1]. These networks often become more formalised and are then referred to as ‘alliances’ [2], [3] of three or often more members. Scholars have traditionally characterised interorganisational networks and alliances as inherently flexible [4]. More recently, the literature argues, however, that there is also a dark flip side to these social structures as they may become overly stable over time and can then ‘entrap’ [5] member organisations in the network in which they are embedded [6]. This can heavily reduce organisations’ strategic flexibility, often to their detriment or at least great costs e.g. in turbulent times [7]–[13]. Examples of cases where lock-ins to interorganisational alliances have been reflected in the (often better known) lock-ins into certain technological choices such as e.g., Qwerty vs. Dvorak, VHS vs. beta, Blu-Ray vs. HD-DVDS etc.

Phenomena of increasingly reduced alternative courses of action and rigid social structures resulting in lock-ins have been described as (organisational) path dependence [14]. This three-phase theory identifies three key features that result in important research challenges: a) that agents are not (fully), aware of and are not (fully) in control of the situation in which seemingly small events lead to their option space narrows down over time and culminating in a critical juncture [14]; b) the reduced option space is owed to the workings of one or several combined positive feedback mechanisms, sometimes referred to as 'self-reinforcing' after the point at which agents certainly lost control [15]; and c) the negative situation of lock-in arises which can no longer "easily be escaped"[16]. Figure 1 below depicts the three-stage model of organisational path dependence:

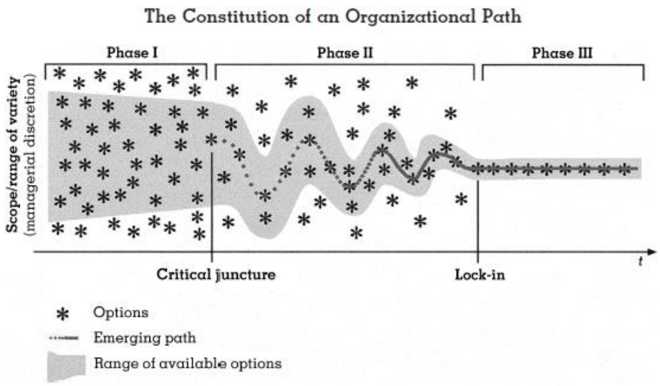

Fig. 1. Organisational path dependence [14]

1.2 Research challenges

Studying path dependence phenomena in general, and particularly those in interorganisational networks, results in formidable research challenges that lead to strong indications for using agent-based social simulation models.

First, the study of path dependence phenomena is often only possible in their final situation, i.e. after the lock-in has occurred since it is at this point that it becomes clear (at least from an external observer's point of view) that the situation has turned negative [16]. Such post-hoc analyses might not be problematic for studying path dependence phenomena in principle, but they limit researchers' ability to study the phenomenon *in vitro* and thus restrict identifying how precisely such a process is unfolding. It can therefore be difficult for empirical agents that are becoming entrapped in a lock-in situation to reflect upon that very situation while entering it. Since the situation is by its very definition undesirable, agents would well have sought to prevent it from happening had they been aware, thus never becoming locked-in in the first place.

Second the positive feedback loops responsible for path dependence lock-ins (e.g. adaptive expectations, learning effects, complementarity effects, coordination effects, etc [14]) do, at least to some extent, develop behind actors backs without being necessarily identifiable or remediable. It is thus challenging to observe or enquire with subjects in empirical contexts about the workings of such mechanisms.

Third, networks constituted by dynamic, multi-directional and often multiplex ties are by their very nature already complex enough to analyse. It is possible to collect empirical social network data to inform network simulations in restricted settings such as classrooms (see e.g. [17]) or online social networks between people [18]. However, in settings in which organisations are of interest, it is much more difficult since in organisations different (and changing) people and different organisational units might have a diversity of connections, even at different times (e.g. [19], [20]).

1.3 Agent-based modelling

In order to study the workings of social mechanisms [21] at play during the development of interorganisational network path dependence and the structures arising from it, the need arises for a formal, i.e. agent-based social simulation, model that enables the study of the complexity of the processes [22] and the emergent structures [23] arising in interorganisational networks over time. Such a simulation model can serve as a “a theoretical experiment that mediates between observations of the phenomenon and natural language descriptions” [24] in that it allows for, and requires a suitable representation of the micro-macro causal linkages [25] under study. The study of path dependence phenomena can especially benefit from the usage of simulation because the method enables theory development [26] regarding the foundations of the mechanisms at play in path dependent processes [16], which is, of course, of key interest.

The process of creating a simulation requires the initially verbal, and subsequently specific formal description of a phenomenon under study, and its ‘translation’ into software code. Forcing researchers to explicate and specify the workings of abstract theoretical concepts, is, of course, beneficial for theory development.

However, validating an agent-based social simulation model not just conceptually, but also empirically has been noted to prove rather difficult [27], and this applies even more so to models of (social) network components and dynamics [28]. Many simulation models simply treat network structures as a ‘given’ and also fixed input and prescribe e.g. mathematical parameters such as a scale-free topology [29] or the degree of centralisation ex-ante or, alternatively, they pre-define agents’ connection behaviour by using mechanisms such as the well-known preferential attachment [30].

The research interest in this study, however, lies on observing network structures as they emerge rather than predetermining them, and also on understanding the condition under which these networks tend to stabilise so as to potentially lock-in their members. Therefore, the focus needs to lie on studying how the “structure of the agent population depends upon emergent social processes.”[31]. Moreover, since we are dealing with interorganisational networks rather than individuals’ social connections, one cannot assume that connections are made in a serendipitous fashion but rather with some form of intent and expectation of that relation being beneficial, which requires a representation in agents’ modelled networking behaviour. Furthermore, given that the network structures of organisations develop behind these agents collective backs, using empirical mathematical network structural data for empirical validation [28] appears to be a fruitless avenue, even if this data, of course, theoretically exists.

Hence, questions then arise regarding how precisely agent make their decisions to connect with others, what information they base their decisions on, and what might lead them to disconnect or even leave a network altogether. Since the different types of network structure arising from agents' networking activities are of key interest here, it is important to gain a clear understanding of motivations, criteria, and decision-making models for providing a suitable decision context from which network structures can then emerge in the simulation model. Thus arises the need for a deep conceptual and empirical grounding, not only for studying the *outcomes* of potentially path dependent dynamics in interorganisational networks of interest herein, but most importantly for learning about and operationalising the *mechanisms and conditions* leading to such potentially overly stable structures so as to allow for model construction.

2 Laying the foundations through qualitative research

Building a social simulation model requires the operationalization and specification of variables and processes and translating these into executable model code for experimentation. Since measures of variables used in many quantitative network modelling approaches are neither available nor readily applicable to present research interests, a different study of empirical network study is required for gaining an empirical grounding. Some scholars approach grounding their model in empirics through an ethnographic approach [32], or in grounded theory [33] research [34], but this can lead to issues if a study of meaning-making becomes very complex and might yield low insight into a phenomenon [35], thus making it difficult to strike a 'lagom' balance between realism and parsimony.

Case studies can be used as a means of developing theory and thus also serve well for model building [36], and the study of (whole) networks through qualitative empirical data collection and analysis approaches has been suggested [37] and been successfully implemented using e.g. observations and interviews [38]. Drawing from several information sources is important in qualitative empirical approaches since the diversity of sources allows for the triangulation of findings [39]. Eisenhardt [40] suggests an 8-step process for case study research with the purpose of conceptual development, which this research follows, with some deviations for brevity of presentation. The definition of the research question/interest and prior discussion of theoretical constructs (step 1) were developed above and elsewhere [13]. The subsequent steps are the selection of cases through theoretical sampling and the development of suitable data collection and analysis methods.

The present research studies interorganisational networks as the core social structure of interest with a focus on identifying stabilisation tendencies of these structures in terms of path dependent interorganisational alliances. This requires a case in a context that exhibits the general properties allowing for networks such as industry alliances to emerge, and that has the potential for learning from several agents' perspective about motives, connection behaviour, and the network dynamics at work. A suitable case was found in the smartphone operating systems' market which serves as the overall case, with two identified embedded sub-cases [41] a) *Open Handset Alliance* – and industry alliance established in 2007 by *Google* around its *Android* operating system and platform – and b) *Symbian Foundation* – a similar network founded in response in 2008 around the now-defunct operating system *Symbian* by its hub-firm *Nokia*. Case b) can serves as the theoretical replication of the former which overall allows a study design with two embedded subcases to follow a beneficial "most similar", i.e. contrasting research design [41].

In terms of crafting instruments (Eisenhardt's step 3) and entering the field (step 4), the study uses a combination of an extensive press article analysis, participant observation at several industry events, and three field experts were interviewed for triangulation in a semi-structured manner that allows for being more conceptually informed than purely narrative interviews. Table 1 below summarises all collected data, including sources and time frames:

Table 1. Case study database

Type of data	Number, sources	Time-frames
Press articles	3180 from 8 sources, through Lexis Nexis database	Feb 2000-Mar 2011
Conference observations	55 observed conference sessions	Jun 2009-Jun 2010
Interviews	3 expert interviews for triangulation	Jan 2009-Jun 2010

Interview data were transcribed, observations were noted down on paper and corroborated and updated with a fellow researcher after the events, and the press articles were digitally parsed and then selected based on relevance. Data analysis (Eisenhardt's step 5) was conducted using a thematic analysis process [42]. Thematic analysis is a method for analysing qualitative data and follows a six-phase process from a) familiarizing with the data, b) generating initial codes, c) searching for themes and patterns, d) reviewing themes, e) defining and naming themes, and then f) writing up the report, which ties in with Eisenhardt's steps 6-8 (shaping hypotheses, enfolding literature, reaching closure), but is shortened substantially herein for brevity reasons.

2.1 Data & Findings

The analysis of the material gathered using thematic analysis involves coding and distilling codes into themes and categories. Codes, categories, and themes were derived *deductively* from theoretical or conceptual aspects [13] and arose *inductively*. I herein concentrate on findings of special relevance for the subsequent creation of the simulation model and point at [13] for much more details on the conceptual framework and a discussion of the findings in the light of it. **Table 2** below overviews key findings.

Table 2. Overview of findings (excerpt)

Themes	Finding/relevance	Usage in/for ABM model
Brokerage & network entry	*Motivation for network membership: information and influence at early stage, careful selection of partners vs. followers	*Part of decision-making function → Agents as information source is key interest for newcomer agents → differences in decision-making
	*Firms differ greatly in their size, age (incumbent vs startup), and resources	*Agent are heterogenous in these three properties
	*Larger firms are strategically member of both alliances (initially)	*Agents can have multiple memberships
Alliance activities	*Network is growing in members	*Entry of new agents over time
	*Increasing number of relations	*Agents require a defined capacity for connections
	*Duration of connections tend to be long-term	*Tie duration as an important tie property to model
Closure, steering & control	*Founding firms matter in connecting others	*Some agents are alliance "founders" and central connection hubs for others in/directly
	*Regular activities such as conferences, collaborative workshops	*Agents cooperate for certain durations of time and periodically
	*Firms engage in alliance internal activities and connect (mostly) within	*Networks become denser over time
Fragmentation (inductive)	*Firms know of issues deriving from technical fragmentation, they seek technical measures to avoid it	*Agents are committing to a group and solution long-term
Lock-in/Exit	*Some agents commit fully to their network, stabilising the industry	*Agents become stable alliance members after a certain time
	*Some firms leave their networks or the industry/become absorbed by others	*Agents need a possibility of leaving the network, and the simulation run
	*With important firms leaving, an alliance ceases to exist	*Alliances exist (membership as individual agent property) and can cease to exist

As overall indications for the subsequent model creation, we can derive that agents are of a rather diverse nature (size, age, and firms' resources vary greatly) ranging from 2-person startups to incumbent global giants with tens of thousands of members. They have similar interests in connecting to advance and stabilise their technological developments, but they have heterogenous means of doing so (resources) and the founding firms of the two industry alliances are the most important connection hubs for others to connect to and through since they broker heavily strategically.

Furthermore, firms tend to commit relatively long-term, some seek to join several alliances (at least initially), but they tend to commit to only one later. It also became clear that after alliances have existed for a while, firms could no longer really exist without being a member of at least one of them, i.e. going alone ceased as a strategic option – due to previous commitments, investment and interactions they became trapped in their own network. Firms that became disconnected for a time either switched alliance, or had strong difficulties in sustaining their businesses, and some even perished, especially when other resource-providing members left an alliance.

Agents exiting their alliance, or the simulation altogether, i.e. the number of agents not remaining constant [31], is thus one important feature. While some firms clearly became locked-in to their networks, it remained unclear how long these processes took relative to the existence of the alliances and also the overall network. Additionally, agents decision-making models seem to differ since the observation and interview data indicate that some firms (e.g. the hub firms) were very strategic in selecting their network partners while especially some of the smaller firms indicated they would just have to join any alliance in in order to survive the new industry developments.

3 Modelling implementation & findings

When building the SimPioN [43] agent-based model in NetLogo [44] subsequent to the qualitative data analysis, it became clear that many implementation choices would need to be informed by the qualitative approach and that many of the extant models or their implementations of network(ing) dynamics (e.g. [45]–[49]could not easily be adapted. Hence, SimPioN was created from the ground up and includes the entities: agents, their links, and alliances as the membership in agents' characteristics. See **Fig. 2** for an overview of the entities and their characteristics. During a simulation run, at every step of the model, agents follow the following processes:

Agents consider other agents, their *alters* (with some limits in their overall perception, and the depth with which they can see into their network, i.e. network path length); they then calculate the attractiveness of the perceived alters for connecting as part of a matching function (building an internal list of partners, depending on their strategy, i.e. decision model); if agents are on each other's lists, then can then decide to connect, as depicted in **Fig. 3** below.

In their decision-making for connecting, agents follow one of three (set via experimental conditions) strategies: optimise, i.e. seek to connect starting at the top of their ranked list; satisfice, i.e. select from an non-ranked list all alters that fulfil a minimum threshold level of attractiveness; or despairing, i.e. select random options without considering any assessment of the alters.

Alter agent's attractiveness is calculated as a score composed of 3 individual characteristics of alters (age, size, resources) and 4 network characteristics (degree centrality, betweenness centrality, familiarity from past connections, alliance membership). The characteristics are not assessed in absolute terms, but always in relation to a connection-seeking agent's own characteristics. Agents can furthermore have preferences in their criteria and weigh individual characteristics, network characteristics, or both. For details and foundational assumptions incl. ODD+D, please see [13], [43].

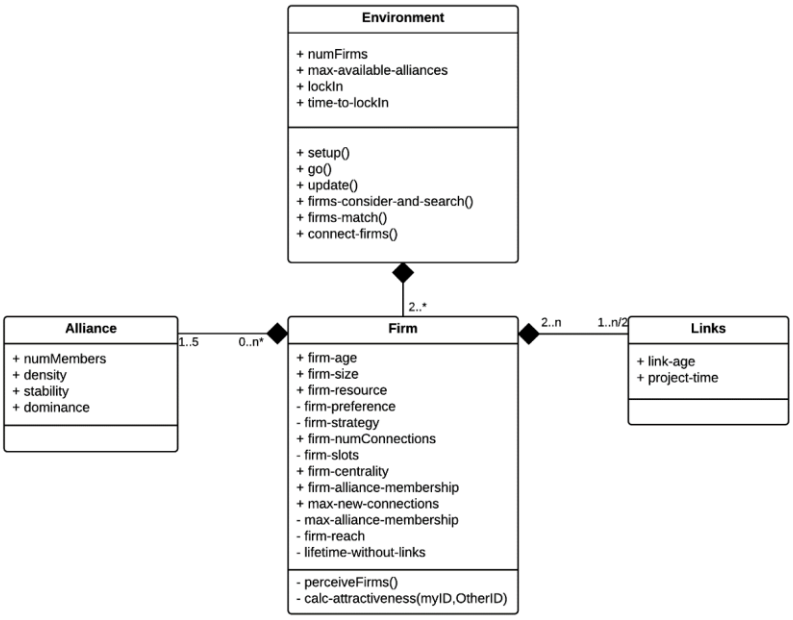

Fig. 2. SimPioN, class diagram with state variables.

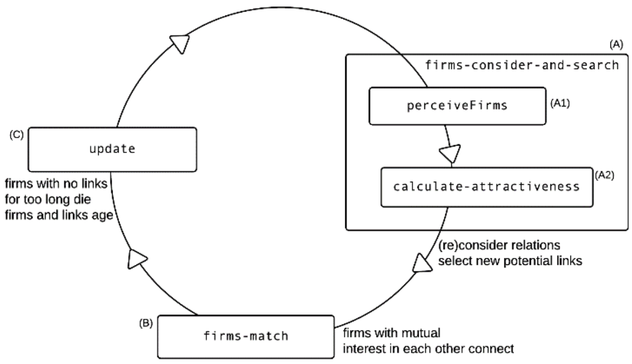

Fig. 3. SimPioN, process diagram.

Having experimented extensively with SimPioN in 3 main experiments (168 design points, with 42,000 total runs, and a total of 10,500,000 repetitions) I briefly summarise important findings of the simulation to the extent that they inform our discussion of grounding ABMs of network dynamics in qualitative case study data and to enable the subsequent discussion of what these empirical findings meant for the simulation design and experimental outcomes.

A) The diversity of decision-making strategies matters greatly for model outcomes. Agents with optimising strategies were less likely to lock-in and took longer to do so, based on their more intense consideration of alters. Satisficing agent scenarios locked-in more often, and faster, and produced the highest network densities. Despairing agent scenarios, unsurprisingly, locking-in at similar rates and even faster.

B) The agent characteristic ‘firm size’ is used as a summary approximation, seeking to capture overall firm qualities but also the resources that define how much capacity a firm has for engaging in networking. This variable thus turned out to be the most influential individual characteristic for agents to become locked in, also in terms of the resulting network densities.

C) For scenarios in which agents consider their alters’ network characteristics most important (i.e. have preferences for these), simulation runs stabilise to high degree and with high resulting network densities. Interestingly, the near-randomness of choosing connection partners for despairing agents revealed longer run durations before lock-in than for optimising of satisficing agent scenarios.

D) Initial conditions such as existing historical connections within alliances before the beginning of a run locked in almost always, and nearly immediately, indicating a very strong effect of history in the network and agents’ inability to break with historically existing structures.

E) Agents without connections exit the simulation in considerable numbers and not all initialised alliances survived all runs beyond some few remaining agents, especially in satisficing scenarios. Maximising agent scenarios showed the highest tendencies for agents to exit and alliances to cease existing which is based on agents seeking to optimise in the face of little choice and thus becoming disconnected for too long.

4 Discussion & Reflection

Overall, the simulation results indicate strong consequences of the implementation and initialisation choices regarding the agents’ decision-making rationale [50] and their preferences when assessing other agents. In my review of the network literature prior to the case study and the modelling, decision-making rationales and preferences for connecting with others were not part of the extant debate. While such aspects might have been approached indirectly in discussions of e.g. homophily in social networks [51], such characteristics of decision-making are not at present part of the study of interorganisational networks – an aspect which I very much encourage discussion of. Interviewees and observation data pointed towards some organisations actually seeking to forge connections rather strategically (optimising) whilst other were happy to go along with any alliance (despairing) so long as they were part of any alliance to not suffer from isolation in the market.

Firm sizes had been indicated to be a factor in agent's networking decisions [52] but the empirical data revealed just how the agents react to this information. Firms participating in the industry events were clear that larger industry players held the ability, not only to broker connections between alliance members but also to hold many networks connections themselves so as to increase cohesion and steering in the alliance.

Agents perceiving (some) network characteristics of their alters is additionally a new ingredient in the decision-making processes of simulated networking agents. The homophily debate on social network often centres on subjects assessing similarities/differences in economic and or personality variables of their alters before seeking to connect. There has been a discussion following Granovetter's seminal work on the fruitfulness of "weak ties" [53], indicating that subjects might assess alters' network position to e.g. identify brokers [5], [7], [54]–[57], so they connect to well-connected alters to gain access to their network resources. However, the strategic usage of this kind of network variable by organisations was not only previously theorised [13] but also clearly voiced during the observation part of the study.

As empirical subjects pointed out, there is, of course, no *tabula rasa* starting condition to interorganisational networks. Certain connections existed historically, and it was clear to informants that these were important. However, it remained conceptually unclear how exactly the networks and their dynamics would be affected by such historical connections. Based on the simulations, we can learn that they have a strong stabilising effect leading to fast and dense lock-ins, especially when agents prefer to assess their alters' network characteristics rather than their individual ones.

Agents exiting was in principle not surprising given the empirical data on e.g. the meagre survival rates of startups. However, empirical subjects shared their perception that "going it alone" would not be possible in the situation of strong competing alliances and that they would rather prefer to be member of any (random) alliance rather than none. Modelling agent network exit and even demise in that manner revealed how such a possibility should be an important feature of network simulation models.

In summary, we can conclude that using qualitative case studies may be useful for creating levels of ontological correspondence [58] suitable for enabling the modelling of abstract social mechanisms. Using a qualitative grounding for a model incorporating emergent network dynamics and structures can be beneficial, specifically for designing the (herein three) decision-making models of agents that generate such structures in the first place. Of course, not only are modelling choices and implementation of utmost importance but also the selection and application of the qualitative methods used – herein case study with press, interview and observation data, and thematic data analysis – matter greatly. Qualitative research methods come with their own challenges, and while their use is generally beneficial and accepted, it behoves us social simulation researchers to reflect on options, choices, and application.

References

[1] K. G. Provan, A. Fish, and J. Sydow, 'Interorganizational Networks at the Network Level: A Review of the Empirical Literature on Whole Networks', *Journal of Management*, vol. 33, no. 3, pp. 479–516, 2007, doi: 10.1177/0149206307302554.

[2] B. Gomes-Casseres, 'Group Versus Group: How Alliance Networks Compete', *Harvard Business Review*, vol. 72, no. 4, p. 62, 1994, [Online]. Available: https://hbr.org/1994/07/group-versus-group-how-alliance-networks-compete

[3] G. Duysters and C. Lemmens, 'Alliance Group Formation', *International Studies of Management & Organization*, vol. 33, no. 2, pp. 49–68, 2003, [Online]. Available: http://content.epnet.com/ContentServer.asp?T=P&P=AN&K=12843452&EbscoContent=dGJyMNXb4kSep7I4wtvhOLCmr0mep65SsKe4TLSWxWXS&ContentCustomer=dGJyMPGptUqxp7RPuePfgeyx%2BEu3q64A&D=buh

[4] W. W. Powell, 'Neither markets nor hierarchy: Networks forms of organization', *Research in Organizational Behavior*, vol. 12, pp. 295–336, 1990.

[5] M. Gargiulo and M. Benassi, 'Trapped in Your Own Net? Network Cohesion, Structural Holes, and the Adaptations of Social Capital', *Organization Science*, vol. 11, no. 2, pp. 183–196, 2000, [Online]. Available: http://content.epnet.com/ContentServer.asp?T=P&P=AN&K=3392731&EbscoContent=dGJyMNXb4kSep7I4wtvhOLCmr0mep65SsKe4TLWWxWXS&ContentCustomer=dGJyMPGptUqxp7RPuePfgeyx%2BEu3q64A&D=buh

[6] B. Uzzi, 'Social Structure and Competition in Interfirm Networks: The Paradox of Embeddedness', *Administrative Science Quarterly*, vol. 42, no. March, pp. 35–67, 1997.

[7] G. Walker, B. Kogut, and W. Shan, 'Social Capital, Structural Holes and the Formation of an Industry Network', *Organization Science*, vol. 8, no. 2, pp. 109–125, 1997, [Online]. Available: http://www.jstor.org/stable/2635305

[8] T.-Y. Kim, H. Oh, and A. Swaminathan, 'Framing interorganizational network change: A network inertia perspective', *Academy of Management Review*, vol. 31, no. 3, pp. 704–720, 2006.

[9] I. Maurer and M. Ebers, 'Dynamics of Social Capital and Their Performance Implications: Lessons from Biotechnology Start-ups', *Administrative Science Quarterly*, vol. 51, pp. 262–292, 2006.

[10] J. Hagedoorn and H. T. W. Frankort, 'The gloomy side of embeddedness: The effects of overembeddedness on inter-firm partnership formation', in *Network Strategy*, T. J. Rowley and J. A. C. Baum, Eds., in Advances in Strategic Management, vol. 25. Bingley: Emerald, 2008, pp. 503–530. doi: 10.1016/S0742-3322(08)25014-X.

[11] M. Burger and J. Sydow, 'How inter-organizational networks can become path-dependent: Bargaining practices in the photonics industry.', *Schmalenbach Busi-*

ness Review, vol. 66, no. 1, pp. 73–99, 2014, [Online]. Available: https://www.wiso-net.de/document/SBRE__011417003

[12] T. Schmidt and T. Braun, ‘When Cospecialization Leads to Rigidity: Path Dependence in Successful Strategic Networks’, *Schmalenbach Business Review*, vol. 67, no. 3, pp. 489–515, 2015, [Online]. Available: https://www.wiso-net.de/document/SBRE__101530004

[13] F. Stöppler, ‘Path dependence in interorganisational networks: An explanatory framework, an empirical case study, and computer simulation experiments’, 2021, doi: 10.17169/refubium-28977.

[14] J. Sydow, G. Schreyögg, and J. Koch, ‘Organizational path dependence: opening the black box’, *Academy of Management Review*, vol. 34, no. 4, pp. 689–709, 2009, [Online]. Available: http://aomarticles.metapress.com/content/n70384h482702l20/?p=c2f835a17893449293f97767c1439d7b&pi=7

[15] J. Sydow and G. Schreyögg, Eds., *Self-reinforcing processes in and among organizations*. Basingstoke, Hampshire: Palgrave Macmillan, 2013.

[16] J.-P. Vergne and R. Durand, ‘The Missing Link Between the Theory and Empirics of Path Dependence: Conceptual Clarification, Testability Issue, and Methodological Implications’, *Journal of Management Studies*, vol. 47, no. 4, pp. 736–759, 2010, doi: 10.1111/j.1467-6486.2010.00913.x.

[17] T. A. B. Snijders and C. Baerveldt, ‘A multilevel network study of the effects of delinquent behavior on friendship evolution’, *The Journal of Mathematical Sociology*, vol. 27, no. 2–3, pp. 123–151, Apr. 2003, doi: 10.1080/00222500305892.

[18] S. M. A. Abbas, ‘An agent-based model of the development of friendship links within Facebook’, *Comput Math Organ Theory*, vol. 19, no. 2, pp. 232–252, Jun. 2013, doi: 10.1007/s10588-013-9156-z.

[19] A. C. Inkpen and E. W. K. Tsang, ‘Social capital, networks, and knowledge transfer’, *Academy of Management Review*, vol. 30, no. 1, pp. 146–165, 2005, doi: 10.5465/AMR.2005.15281445.

[20] W. Tsai, ‘Knowledge transfer in Intraorganizational networks: effects of network position and absorptive capacity on business unit innovation and performance’, *Academy of Management Journal*, vol. 44, no. 5, pp. 996–1004, 2001.

[21] P. Hedström and R. Swedberg, ‘Social Mechanisms’, *Acta Sociologica*, vol. 39, no. 3, pp. 281–308, 1996, doi: 10.1177/000169939603900302.

[22] J. R. Harrison, Z. Lin, G. R. Carroll, and K. M. Carley, ‘Simulation modeling in organizational and management research’, *Academy of Management Review*, vol. 32, no. 4, pp. 1229–1245, 2007.

[23] G. N. Gilbert and K. G. Troitzsch, *Simulation for the social scientist*, 2nd ed. Buckingham: Open University Press, 2005.

[24] B. Edmonds and D. Hales, ‘Computational Simulation as Theoretical Experiment’, *Journal of Mathematical Sociology*, vol. 29, no. 3, pp. 209–232, 2005, doi: 10.1080/00222500590921283.

[25] P. Hedström and P. Ylikoski, ‘Causal Mechanisms in the Social Sciences’, *Annual Review of Sociology*, vol. 36, no. 1, pp. 49–67, 2010, doi: 10.1146/annurev.soc.012809.102632.

[26] J. P. Davis, K. M. Eisenhardt, and C. B. Bingham, ‘Developing theory through simulation methods’, *Academy of Management Review*, vol. 32, no. 2, pp. 490–499, 2007.

[27] R. M. Burton and B. Obel, ‘The validity of computational models in organization science: From model realism to purpose of the model’, *Comput Math Organiz Theor*, vol. 1, no. 1, pp. 57–71, Oct. 1995, doi: 10.1007/BF01307828.

[28] S. M. A. Abbas, S. J. Alam, and B. Edmonds, ‘Towards Validating Social Network Simulations’, in *Advances in Social Simulation*, B. Kamiński and G. Koloch, Eds., in Advances in Intelligent Systems and Computing, vol. 229. Berlin, Heidelberg: Springer Berlin Heidelberg, 2014, pp. 1–12. doi: 10.1007/978-3-642-39829-2_1.

[29] T. G. Meyer, *Path dependence in two-sided markets: A simulation study on technological path dependence with an application to platform competition in the smartphone industry: PhD thesis*. Berlin: Freie Universität Berlin, 2012.

[30] R. Albert and A.-L. Barabási, ‘Statistical mechanics of complex networks’, *Rev. Mod. Phys.*, vol. 74, no. 1, pp. 47–97, Jan. 2002, doi: 10.1103/RevModPhys.74.47.

[31] S. J. Alam, B. Edmonds, and R. Meyer, ‘Identifying Structural Changes in Networks Generated from Agent-Based Social Simulation Models’, in *Agent Computing and Multi-Agent Systems*, A. Ghose, G. Governatori, and R. Sadananda, Eds., in Lecture Notes in Computer Science, vol. 5044. Berlin, Heidelberg: Springer Berlin Heidelberg, 2009, pp. 298–307. doi: 10.1007/978-3-642-01639-4_26.

[32] L. Yang and N. Gilbert, ‘GETTING AWAY FROM NUMBERS: USING QUALITATIVE OBSERVATION FOR AGENT-BASED MODELING’, *Advs. Complex Syst.*, vol. 11, no. 02, pp. 175–185, Apr. 2008, doi: 10.1142/S0219525908001556.

[33] R. Suddaby, ‘From the editor: What Grounded Theory is not’, *Academy of Management Journal*, vol. 49, no. 4, pp. 633–642, 2006.

[34] M. Neumann, ‘Grounded Simulation’, in *Advances in Social Simulation*, B. Kamiński and G. Koloch, Eds., in Advances in Intelligent Systems and Computing, vol. 229. Berlin, Heidelberg: Springer Berlin Heidelberg, 2014, pp. 351–359. doi: 10.1007/978-3-642-39829-2_31.

[35] N. Siggelkow, ‘Persuasion with case studies’, *Academy of Management Journal*, vol. 50, no. 1, pp. 20–24, 2007.

[36] M. Gibbert, W. Ruigrok, and B. Wicki, ‘What Passes as a Rigorous Case Study?’, *Strategic Management Journal*, vol. 29, no. 13, pp. 1465–1474, 2008.

[37] B. Hollstein, ‘Qualitative Methoden und Netzwerkanalyse - ein Widerspruch?’, in *Qualitative Netzwerkanalyse*, B. Hollstein and F. Straus, Eds., Wiesbaden: VS, Verlag für Sozialwissenschaften, 2006, pp. 11–35.

[38] T. A. Schenk, ‘Generating an Agent Based Model from Interviews and Observations: Procedures and Challenges’, in *Advances in Social Simulation*, B. Kamiński and G. Koloch, Eds., in Advances in Intelligent Systems and Computing, vol. 229. Berlin, Heidelberg: Springer Berlin Heidelberg, 2014, pp. 361–372. doi: 10.1007/978-3-642-39829-2_32.

[39] U. Flick, ‘Triangulation in der qualitativen Forschung’, in *Qualitative Forschung*, U. Flick, E. von Kardorff, and I. Steinke, Eds., in Rowohlts Enzyklopädie. Reinbek bei Hamburg: Rowohlt Taschenbuch, 2005, pp. 309–318.
[40] K. M. Eisenhardt, ‘Building Theories from Case Study Research’, *Academy of Management Review*, vol. 14, no. 4, pp. 532–550, 1989, doi: 10.2307/258557.
[41] R. K. Yin, *Case study research: design and methods*, 4th. London: Sage, 2009.
[42] V. Braun and V. Clarke, ‘Using thematic analysis in psychology’, *Qualitative Research in Psychology*, vol. 3, no. 2, pp. 77–101, Jan. 2006, doi: 10.1191/1478088706qp063oa.
[43] F. Stöppler and N. Wijermans, ‘SimPioN - Simulating Path dependence in interorganisational Networks v1.0.0’, *CoMSES Computational Model Library*, Jan. 2021, Accessed: May 11, 2023. [Online]. Available: https://www.comses.net/codebases/1e8b7d0e-80de-4373-aa8f-d3c6a0336ead/releases/1.0.0/
[44] U. Wilensky, ‘NetLogo’. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL, 2016 1999. [Online]. Available: https://ccl.northwestern.edu/netlogo/
[45] A.-L. Barabási and R. Albert, ‘Emergence of Scaling in Random Networks’, *Science*, vol. 286, no. 5439, pp. 509–512, 1999, doi: 10.1126/science.286.5439.509.
[46] A. Pyka, N. Gilbert, and P. Ahrweiler, ‘Agent-based Modelling of Innovation Networks - The Fairytale of Spillover’, in *Innovation networks*, A. Pyka and A. Scharnhorst, Eds., in Understanding complex systems. Berlin: Springer, 2009, pp. 101–126.
[47] R. Guimera, B. Uzzi, J. Spiro, and L. A. N. Amaral, ‘Team assembly mechanisms determine collaboration network structure and team performance’, *Science*, vol. 308, no. 5722, pp. 697–702, 2005, doi: 10.1126/science.1106340.
[48] E. Bakshy and U. Wilensky, ‘NetLogo Team Assembly model’. Evanston, IL, 2007. Accessed: Jan. 26, 2016. [Online]. Available: http://ccl.northwestern.edu/netlogo/models/TeamAssembly
[49] L. Walker and P. Davis, ‘Modelling “Marriage Markets”’, *JASSS-Journal of Artificial Societies and Social Simulation*, vol. 16, no. 1, 2013, doi: 10.18564/jasss.2106.
[50] S. J. Alam and A. Geller, ‘Networks in Agent-Based Social Simulation’, in *Agent-Based Models of Geographical Systems*, A. J. Heppenstall, A. T. Crooks, L. M. See, and M. Batty, Eds., Dordrecht: Springer Netherlands, 2012, pp. 199–216. doi: 10.1007/978-90-481-8927-4_11.
[51] M. McPherson, L. Smith-Lovin, and J. M. Cook, ‘Birds of a Feather: Homophily in Social Networks’, *Annu. Rev. Sociol.*, vol. 27, no. 1, pp. 415–444, Aug. 2001, doi: 10.1146/annurev.soc.27.1.415.
[52] J. Fortwengel and J. Sydow, ‘When Many Davids Collaborate with One Goliath: How Inter-organizational Networks (Fail to) Manage Size Differentials’, *British Journal of Management*, vol. 23, p. 434, 2018, doi: 10.1111/1467-8551.12313.

[53] M. S. Granovetter, 'The Strength of Weak Ties', *American Journal of Sociology*, vol. 78, pp. 1360–1380, 1973, [Online]. Available: http://www.jstor.org/stable/2776392

[54] J. S. Coleman, 'Social capital in the creation of human capital.', *American Journal of Sociology*, vol. 94, pp. 95–120, 1988, [Online]. Available: http://www.jstor.org/stable/2780243

[55] R. S. Burt, *Structural holes: The social structure of competition*. Cambridge, MA: Harvard University Press, 1992.

[56] R. S. Burt, 'Structural Holes versus Network Closure as Social Capital', in *Social capital*, N. Lin, K. Cook, and R. S. Burt, Eds., New York: Aldine De Gruyter, 2001, pp. 31–56.

[57] N. Lin, 'Building a network theory of social capital', in *Social capital*, N. Lin, K. Cook, and R. S. Burt, Eds., New York: Aldine De Gruyter, 2001, pp. 1–25.

[58] F. Squazzoni, 'The impact of agent-based models in the social sciences after 15 years of incursion', *History of Economic Ideas*, vol. 18, pp. 197–233, 2010.