Navigating the innovation complexities across supply networks using attractors

A multi-level perspective

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August 25, 2023

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Introduction

Research context

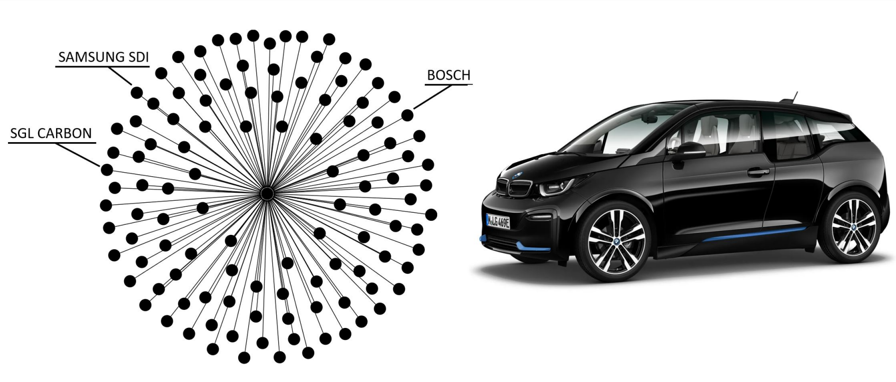

Figure 1: The first tier supply network of BMW i3.

Key definitions

Table 1: Key definition used in this study

Term	Definition
Supply network	A focal firm's direct ties to each of its supply network partners (e.g., suppliers and customers), but also its indirect ties to partners of the firm's direct partners
Complexity	The degree of varied elements and their interactions within a system
Innovation complexity	The extent of diverse elements within the supply network system and their interactions involved in developing innovative products, services or processes

Research gap

Although the negative effect of supply chain complexity on a firm's operational and financial performances is rather straightforward, in innovation management, complexity appears to be a requirement rather than a constraint[1].

To address the research gaps identified in recent operations management research[2], we aim to study how behavior and routine patterns shape innovation capabilities in firms and supply networks. This approach will help us better understand the core components of how innovations emerge and proliferate within supply networks.

[1] Thomas Y. Choi, Kevin J. Dooley, and Manus Rungtusanatham. "Supply networks and complex adaptive systems: Control versus emergence". In: *Journal of Operations Management* 19 (3 2001), pp. 351–366.

[2] Anand Nair and Felix Reed-Tsochas. "Revisiting the complex adaptive systems paradigm: Leading perspectives for researching operations and supply chain management issues". In: *Journal of Operations Management* 65 (2 2019), pp. 80–92.

Research question

In recent years, there has been an increasing focus in supply chain management literature on utilizing a Complex Adaptive Systems (CAS) approach to effectively capture the inherent complexity and dynamism of supply networks. Drawing from this body of work, we embrace the CAS perspective to gain deeper insights into the complexities surrounding innovation within supply networks.

RQ: What kinds of complexities associated with the innovation process unfold across multi-level supply networks?

Theoretical background

Supply network as complex adaptive system

Supply network is not only a complex system composed of a large number of interconnected actors (e.g., suppliers, buyers, and non-governmental organizations) but also a complex adaptive system that is emerging, self-organizing, dynamic, and evolving.

The firm, thus, is considered embedded in a large network of interconnected supply partners that it shapes and is shaped by[3].

[3] Leonardo Marques and Marina Dastre Manzanares. "Towards social network metrics for supply network circularity". In: *International Journal of Operations & Production Management* 43 (4 2023), pp. 595–618.

Embracing complexity

Operations and supply management research tends to oversimplify organizational and inter-organizational structures and often assumes linear relationships between practices and performance[4]. OSCM processes, however, are inherently non-linear, adaptive, and complex, making them difficult to fully comprehend.

Oversimplification of these processes may lead to their incomplete understanding, thus impeding the development of effective strategies to govern them. As such, taking a comprehensive, dynamic, multi-level research approach to complex OSCM processes is vital for enhancing their functioning[5].

[4] Anand Nair and Felix Reed-Tsochas. "Revisiting the complex adaptive systems paradigm: Leading perspectives for researching operations and supply chain management issues". In: *Journal of Operations Management* 65 (2 2019), pp. 80–92.

[5] Craig R. Carter, Dale S. Rogers, and Thomas Y. Choi. "Toward the Theory of the Supply Chain". In: *Journal of Supply Chain Management* 51 (2 Apr. 2015), pp. 89–97.

Innovation complexities across supply networks

The potential for innovation thus lies at the intersection of order and chaos[6]. Innovation can be hindered by excessive control as well as by unrestrained freedom.

The success of product or process innovation depends on a combination of knowledge, capabilities, and resources that either stem from internal sources or are externally acquired. Supply network partners are recognized as valuable sources that contribute to the firm's innovation performance by augmenting its internal knowledge pool through complementary knowledge transfer[7].

[6] Yu-Ting Cheng and Andrew H. Van de Ven. "Learning the Innovation Journey: Order out of Chaos?" In: *Organization Science* 7 (6 Dec. 1996), pp. 593–614.

[7] S. M. Wagner. "Tapping supplier innovation". In: *Journal of Supply Chain Management* 48 (2 2012), pp. 37–52.

Attractors of dynamic systems

Complex systems are characterized by behavior that is influenced by the initial conditions and guided by dynamic attractors.

Initial conditions

In complex systems, small changes in the initial conditions can lead to dramatically different outcomes, a phenomenon known as sensitivity to initial conditions.

Attractors

Attractors represent the system's long-term behavior and can guide the system towards certain patterns or states.

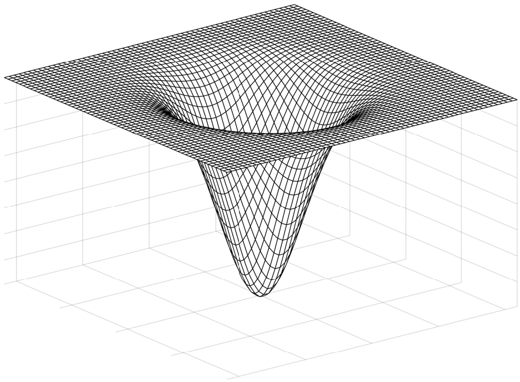

Figure 2: Visual representation of point attractor

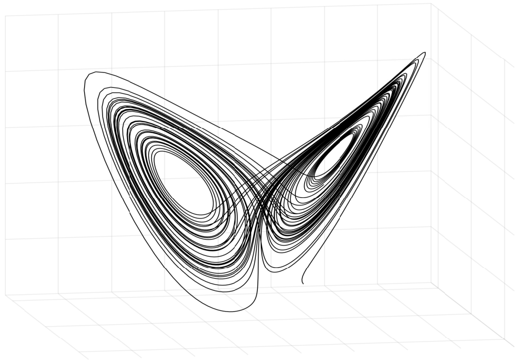

Figure 3: Visual representation of strange attractor

Research design

Sample selection

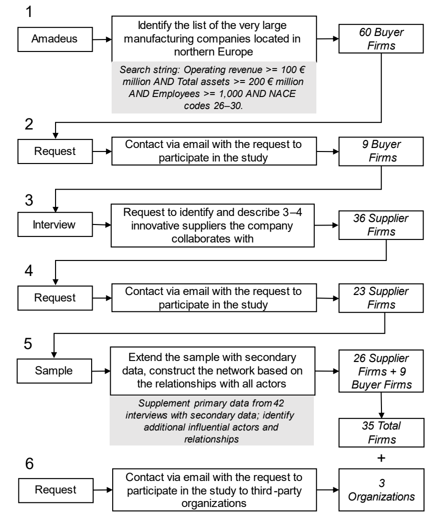

Figure 4: The sampling process

Analysed network

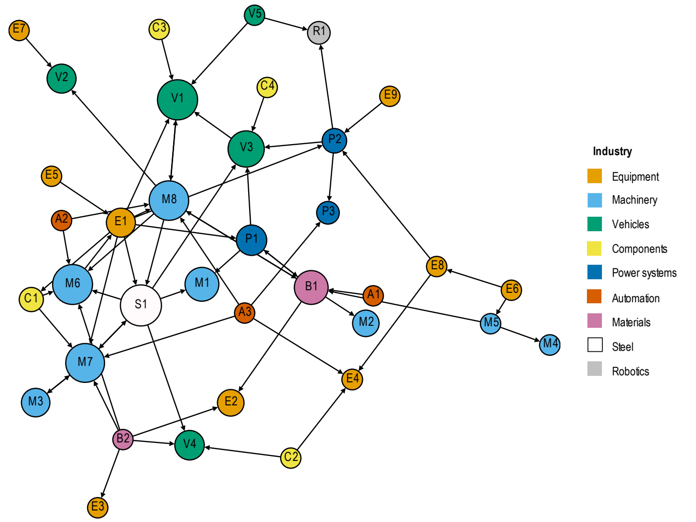

Figure 5: Analyzed supply network. Node size is determined by Eigenvector centrality.

Data analysis

- We first inductively generated first-order open codes without any predefined coding structure.
- Next, we inductively developed the first-order concepts without following any specific coding structure.
- Then, we aggregated the generated first-order codes under the second-order themes guided by theory.
- Finally, we organized and interconnected the identified complexities and attractors across different levels of the supply network.

Complex adaptive system research design considerations

Table 2: Reserach design dimentions

Dimension	Key methodological issues	Research approaches
Conceptual (boundary and perspectives)	Ill-defined supply network boundaries; different languages and labels used by actors	Process-function approach, secondary data and confirmatory interviews were used to identify and verify the boundaries
Structural (hierarchies and relationships)	Hierarchical and not homogeneous structures and relationships in the supply network requiring holistic view	Supply network analysis; simple mapping of appraches while analysing the interview data
Temporal (dynamics and coevolution)	The system is constantly evolving, different part of the systems change differently	Multiple 'snapshots' of each case based on interview and archival data, key trends mapped over time

Results and findings

Network evolution

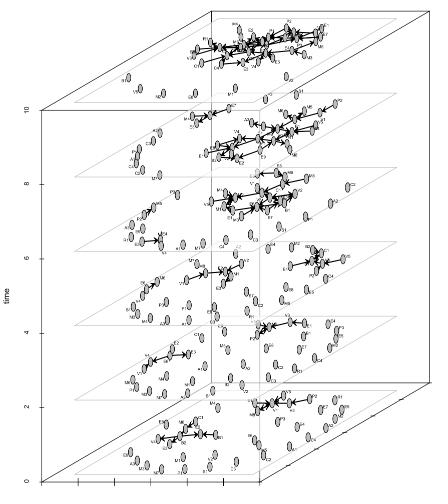

Figure 6: Timestamps of the evolution of analyzed supply network

Initial conditions

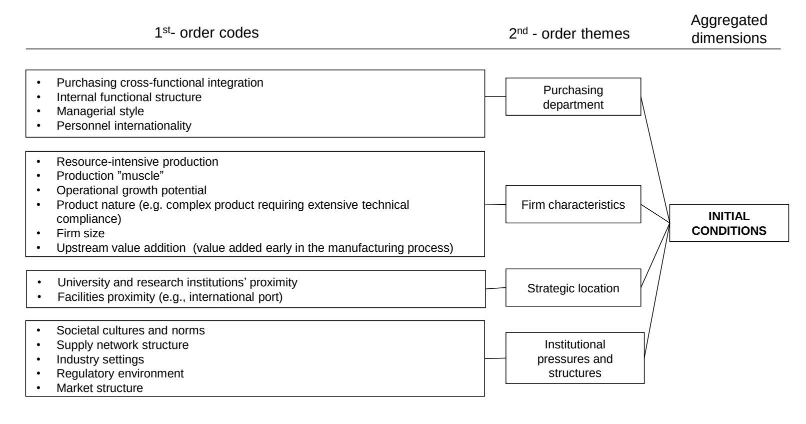

Figure 7: Initial conditions (coding tree)

Innovation complexities

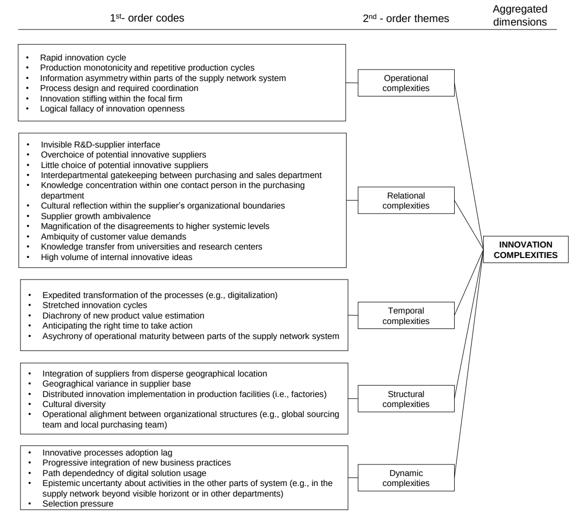

Figure 8: Innovation complexities (coding tree)

Dynamic attractors

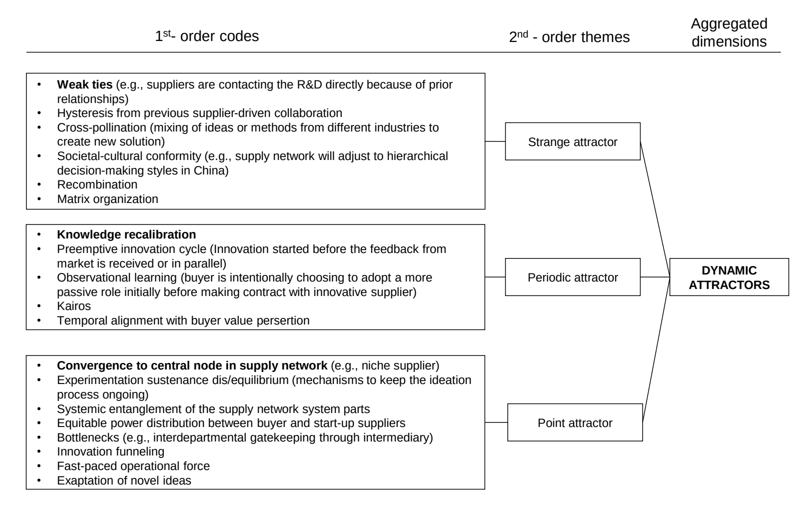

Figure 9: Dynamic attractors (coding tree)

Initial conditions as determinants of complexities

Innovation complexities

Initial conditions	Relational complexity	Structural complexity	Operational complexity	Temporal complexity	Dynamic complexity
Purchasing department	• Invisible R&D-supplier interface • Interdepartmental gatekeeping • Knowledge concentration • Magnification of the disagreements • Ambiguity of value demands	• Integration of suppliers from disperse geographical location		• Expedited transformation • Diachrony of new product value estimation	
Firm characteristics	• Over/under choice of potential innovative suppliers • High volume of internal innovative ideas	• Geographical variance in the supplier base	• Production monotonicity • Information asymmetry • Process design and required coordination • Logical fallacy of innovation openness		• Innovative processes adoption lag • Path dependency of digital solution usage
Strategic location	• Knowledge transfer from universities and research centers				
Institutional pressures and structures	• Cultural reflection • Supplier growth ambivalence	• Distributed innovation implementation in production facilities • Cultural diversity • Operational alignment between organizational structures	• Rapid innovation cycle • Innovation stifling	• Anticipating the right time to take action • Rapid innovation cycle • Asynchrony of operational maturity	• Progressive integration of new business practices • Epistemic uncertainty about activities in the other parts of the system • Selection pressure

Figure 10: The relationship between initial system conditions and innovation complexities

Multi-level framework

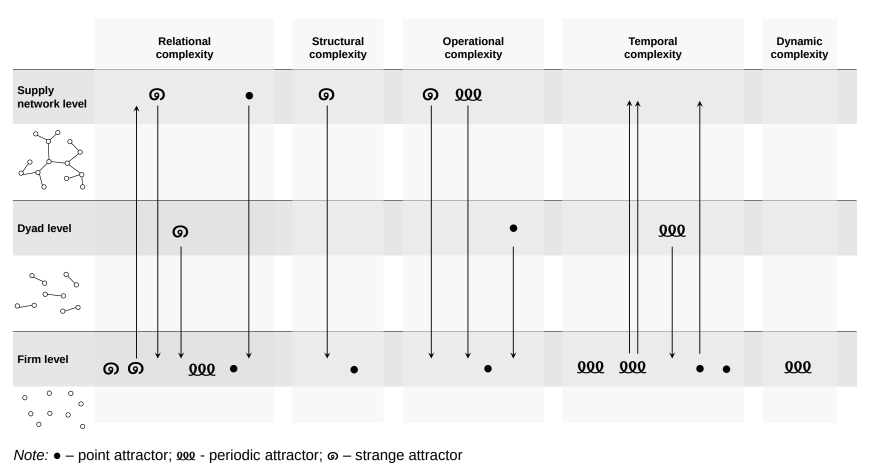

Figure 11: Relationship between innovation complexities and attractors across supply network levels

Main findings

- Across supply networks, the primary forms of innovation complexity frequently observed are relational and structural complexities.
- Among the diverse set of initial conditions that contribute to the manifestation of these innovation complexities, those associated with institutional pressures and structures tend to be the most significant. In fact, these conditions lead to the emergence of all identified types of complexities.
- Dynamic attractors are primarily observed at the micro, or firm, level. However, within the broader network level, the strange attractor type tends to be the most prevalent.

Discussion and conclusion

Conclusion

Our approach was a theory refinement methodology using a single-case study with multiple embedded units of analysis, namely 35 organizations embedded in a single supply network.

Based on our analysis, we identify and describe various types of innovation complexities that occur within the boundaries of a single firm, in dyadic relationships, and across the multi-actor network.

Additionally, we studied three types of attractors such as point attractors, periodic attractors, and strange attractors which exist across and shape the processes within the supply network.

Contributions

It complements and extends research on supply networks as complex adaptive systems[8], research focused on emergence and development of innovation across supply networks[9], research focused on innovation complexities[10].

Moreover, while the previous research has introduced the concept of attractors as a means to leverage the potential of creative chaos[11], this study extends the concept of attractors to the multi-level supply network perspective.

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[8]Thomas Y. Choi, Kevin J. Dooley, and Manus Rungtusanatham. "Supply networks and complex adaptive systems: Control versus emergence". In: *Journal of Operations Management* 19 (3 2001), pp. 351–366.

[9]Anand Nair and Felix Reed-Tsochas. "Revisiting the complex adaptive systems paradigm: Leading perspectives for researching operations and supply chain management issues". In: *Journal of Operations Management* 65 (2 2019), pp. 80–92.

[10]Raghu Garud, Philipp Tuertscher, and Andrew H. Van De Ven. "Perspectives on innovation processes". In: *Academy of Management Annals* 7 (1 2013), pp. 775–819. DOI: `10.1080/19416520.2013.791066`.

[11]Shekhar Jayanthi and Kingshuk K. Sinha. "Innovation implementation in high technology manufacturing: A chaos-theoretic empirical analysis". In: *Journal of Operations Management* 16 (4 1998), pp. 471–494.

Thank you!

Feedback and discussion

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Case example

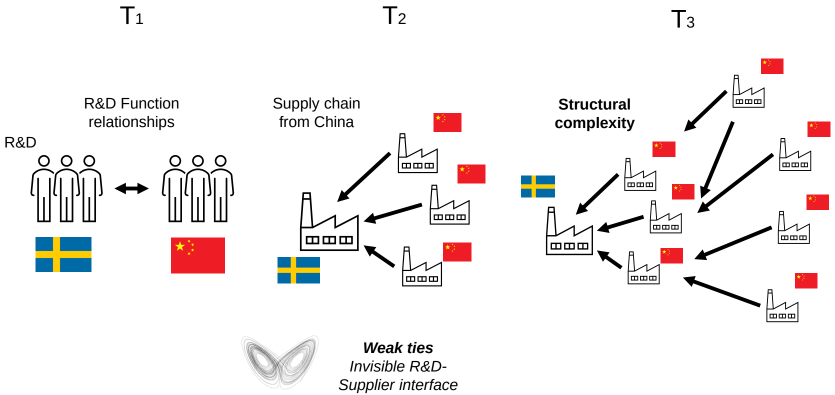

Figure 12: Case P1 - Electric battery manufacturer

Limitations

Conclusions are limited as the studied supply network is not global and is located in a single region.

Another limitation of the research is the focus on manufacturing companies. While we extended our study to include other types of organizations, the findings of the study may be less applicable to service-oriented supply networks.

Other limitations.