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Agility Enablers in Production Networks – Pooling and Allying of Manufacturing Resources

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Abstract
The organizational structure of a production network holds strong potential to enable agility in manufacturing, if its configuration is expedient. Therefore, this paper explores configurational indicators on production networks. Based on a systematic literature review, 18 articles in 13 peer-reviewed journals are identified. In a three-step approach the implications of different configurational designs on the exploitation and exploration of production network resources are analyzed. The main finding is a different configurational requirement for diverging types of volatility: Market-based volatility requires a redundant network capacity pool, as production shifts and multiple routing can leverage the exploitation of manufacturing resources. Technology-based volatility asks for complementary network capacity, as exploration is increased by a more dynamic distribution of value creation and the built-in real option of innovative resource allocation.

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1. Introduction
Manufacturing systems are challenged by volatile markets, intensive competition and turbulent surroundings based on the high interconnectedness of its actors [1]. This results in an omnipresent risk of dramatic sales downturns, threatening the efficiency of manufacturing systems, if these cannot adapt. As complexity is increasing, the required robustness and resilience of production may reach a limit. As a consequence, additional agility is essential to meet current challenges.

One way to cope with this new reality results from the formation of production networks. In doing so, environmental challenges can be addressed by replacing external dependence by internal dependence within the network. On the one hand, this trade-off holds a strong potential as networks can face global change drivers on the highest organizational level: External impacts can be weakened on the network level before reaching the production’s shop floor level. On the other hand, the configurational design of production networks is critical to face external and organizational complexity [2]. Several studies state, that production networks only add value instead of re-distributing profits if its configuration is systematically designed [3-5]. Hence, this paper aims on the identification of indicators to determine which kind of network configuration is sufficient to address different turbulences in manufacturing.

2. Conceptual Framework
The production network, an organizational structure between market and hierarchy, can be defined as the voluntary arrangement between firms to exchange and share resources and to engage in the codevelopment or provision of products, technologies and assets [6]. Another definition is focusing on the “mutual use of resources and the joint planning of the value-added process” to access additional options within the network [7]. Both definitions underpin the utilization of combined resources, as “single steps of the value-added process are carried out at globally distributed locations” [8]. In doing so, the production network holds a significant potential to cope with change drivers and enable agility in manufacturing by reduced market dependency, informational advantages, collective risk pooling, and the in-/outsourcing of...
production processes within the network [4]. In this context, two different agility enabling concepts have been identified, which utilize different modes of action to facilitate manufacturing agility in production networks [9]. These two agility enabling concepts, which lay the basis of this article, go back to the theoretical framework proposed by Nohria and Garcia-Pont, who described networks as ‘strategic blocks’ based on the structure of the network partners’ capabilities [10]. In doing so, two types of strategic blocks were identified and empirically proven by findings from the global automotive industry: the complementary block, which composes of companies with different capabilities, and the pooling block, which composes of firms with similar capabilities. Ideally both types of strategic blocks grant access to a similar set of strategic capabilities for its partners. On this basis two agility enabling concepts are introduced: One is the pooling concept, based on the multiple routing approach that supports demand shifts on the fundament of similar production capacity within the network [11]. Two is the allying concept based on complementary production capacity, which is using the effectiveness of the operator model to release utilization of infrastructure from its possession [4]. This supports local advantages within the network by enabling higher degrees of freedom in the distribution of value creation. Both concepts are leveraged by the organizational structure of the production network and support an efficient and robust manufacturing process [5].

However, the two agility enabling concepts require a complementary design of production network configuration. While the pooling concept is facilitated by a horizontal, global and heterarchical network structure, the allying concept requires a vertical, consolidated and hierarchical structure, while its global orientation is merely optional [4]. Both agility enabling concepts address volatility. Hence, the most relevant factor for selecting the proportionate concept seems to be the specific change driver of the production network. To analyze the two agility enabling concepts, their specific agility gains are tested against different types of volatility for two contrary production strategies, namely exploitation and exploration of manufacturing resources. This is done in line with Lim et al., who state that the rent creation can focus on distinctive mechanisms: the exploitation and the exploration of resources [12]. The authors emphasize the importance of the appropriate retrenchment strategy to protect a certain business model.

The pooling concept favors production order shifts and the utilization of locational advantages between manufacturing locations. This enables especially (fixed-)cost intensive production systems to cope with the risk of high demand fluctuation. This is highly relevant for a successful execution of the exploitation strategy. The allying concept facilitates access to additional restricted resources. This is crucial in innovative environments with complex products. In line with the exploration strategy, the combination of distinct resources creates unique capabilities, while the entrepreneurial risk taking is shared within the network. For these reasons, two change drivers are selected for the paper’s research question, which the production network shall bridge: market-based volatility and technology-based volatility. Market-based volatility is characterized by an environment of rapid volume and product-mix turbulence in demand and supply, which is in particular stressing the exploitation strategy. On the other hand, technology-based volatility occurs in highly innovative environments with major risks of technology leaps and unforeseeable product life cycles.

The aim of this paper is the determination of indicators on production network configuration to bridge different types of volatility based on the two agility enabling concepts of resource pooling and resource allying. Therefore, production networks shall be configured in line with the specific environmental turbulences of its manufacturing systems.

Based on these assumptions, the following research question is proposed: Which indications for the configurational design of production networks can be derived from the current economic literature to compensate market-respectively, technology-based volatility?

![Fig. 1: Conceptual Research Framework](image-url)

3. Method

As explained in the previous chapter, this paper’s goal is to analyze to what extent the type of volatility in the production network’s environment is relevant for choosing an agility enabling concept. To inquire this, a systematic literature review shall assess and analyze the findings of academic articles on how production network configuration can overcome volatility. To structure the literature review, the methodology of David & Han is applied, who used a systematic assessment of evidence to explore a research topic by including a large body of existing literature, which is subsequently scaled down systematically to identify an adequate sample of research results as an isolated and manageable basis for further inquiry [13]. This methodology is particularly suitable for testing an explorative hypothesis within a complex research area, as applied for similar fields of research [14-17]. Therefore, the selected procedure does not seek to include all relevant articles on production networks. Instead, it aims to identify a representative as well as manageable sample of studies to evaluate the given research question.

The methodology is chosen due to certain circumstances. First, the systematic literature review is designed for approaching abstract research concepts, especially if these are difficult to measure like the concept of agility [8]. Second, it permits access to an object of research from different scientific disciplines. This becomes necessary as the production network is present in several fields of research like operations management, organizational studies or strategy. Therefore, a keyword-based search on JSTOR seems appropriate, since this database includes over 1200 academic records.
journals with a broad extent of different academic disciplines, which does not limit the literature review to one field. Third, the production network represents an “indirect empirical object” as it cannot be monitored directly [4]. Consequently, appropriate indicators are required to gain additional perception. To deal with this, the systematic literature review offers a combination of different articles, which results in a diversified picture of this indirect empirical object. The consideration of articles is restricted to peer-reviewed journals to reflect a certain methodical and conceptual quality of the articles and to ensure that only promising indicators to approach this research object are included. The thereby associated risk of availability bias when excluding non-referred articles can be considered minimal, as Hunter & Schmidt found out that results of published and unpublished studies are essentially identical [18]. To identify relevant articles seven keywords were selected: “network”, “flexibility”, “manufacturing”, “capacity management”, “configuration”, “production shift” and “multinational”. These general keywords were used, as more specific expression would have eliminated references with divergent definitions. On this basis 205 articles were identified.

To extract the relevant articles for this paper’s focus, the abstracts of these articles were analyzed with respect to meet three criteria: First, the research object of the article has to be the production network as a facilitator of competitive advantage in a congruent coverage of the definition in chapter two. Second, the impacts of production networks as agility enabler need to be evaluated in some way. Third, the article needs to draw a distinction between diverse types of network configuration to allow an assessment of the different configurational designs. The research methods of the articles were not considered crucial, conceptual as well as empirical studies were included. On this basis, 9 articles could be identified. To increase the relevant sample, the references of these papers were also comprised, which increased the number of relevant articles to 21. In a further step, articles from the same authors, which contained similar results, were separated. This resulted in a final sample of 18 articles.

This sample size is considered sufficient with regards to the highly strategic research object of network agility, especially as one of these articles contains references for both agility enabling concepts [19]. In comparison with recent systematic literature reviews with similar quantitative topics Stankovic & Luthans considered 19 articles in their research, while Campbell included 17 articles [14,17].

The evolved literature sample arises from 13 peer-reviewed academic journals listed in table 1. Based on the Journal Rating of the Australian Business Deans Council, all these journals are ranked between A* and B [20]. The area of the journals’ research discipline is primarily operations management; other contributions are given from international business, organizational studies and strategy.

The applied methodology further explores, to what extent the production network in its different configurational designs is enabling agility to meet market- respectively technology-based volatility in manufacturing. Therefore, the identified literature sample is consistently surveyed in a three-step approach to classify the identified articles within the context of the research question. First, the network configuration of the considered articles is associated to one of the two agility enabling concepts. This is done in line with the definition of chapter two: If the agility gain from the production network is based on the consolidation of horizontal-oriented, redundant resources this indicates resource pooling. In contrast, the production network agility arising from the combination of vertical-oriented, complementary resources implies resource aligning.

Second, the articles are deconstructed in terms of the kind of turbulence, which is addressed by the considered production network. The distinction between market- respectively technology-based volatility is done by analyzing the change drivers, to which the articles refer, which need to be coped with the agility gains from production networks.

Third, the articles are sorted by their type of volatility as well as by their agility enabling concept based on their configurational designs of the production networks. This combined approach of systematic identification and classification of academic articles lays the basis for this paper.

4. Results

Based on the methodology presented above, this chapter analyzes the single articles of the literature sample to assess the interrelation between the volatility type and the agility enabling concept of the production network derived from its configurational design. The results of this procedure are visualized in table 2, where the 18 articles are classified by their type of volatility and their agility enabling concept. Furthermore, the table includes information regarding the articles’ research method.

To begin with production networks as an agility enabler for market-based volatility, the relevant articles address the main challenges for the exploitation strategy. These are demand and cost turbulences, especially when the imperative of extensive capacity and material cost structures is present.

In the conceptual section, Colotla et al. showed, based on the resource-based view on factory- and network-level, that the potential of network capacity can “be utilized optimally by shifting production volumes” [19]. Hereby the usage of network resources is leveraged, which increases the capacity efficiency and minimizes the risks in volatile market demands by a co-operatively managed resource pool based on capacity optimization and collaboration, not on ownership.
A similar aspect is illustrated by Ahlert et al., who established a model to address capacity problems by capacity pools on network level, which are shared on the basis of reservation requests [21]. The pricing of these reservations evolves from the actual capacity utilization. Therefore, the production order rejection is minimized within the network and the utilization risks are born from the whole network.

Wu & Kleindorfer established a theoretical framework with a capacity-portfolio-perspective to illustrate the price of capacity usage options [22]. In this interaction process the organizational structure of production networks can create the required platform for information exchange of demand fluctuation and the long-term perspective, in which the exchange and improvement potential is given to manage capacity efficiently and flexible.

Huchzermeier & Cohen applied a stochastic quantitative model to evaluate global manufacturing strategies by its switching costs [23]. Results confirm the production network as an option to address fixed operating costs by pooling production capacity, which results in additional flexibility.

Lei et al. identified production networks as a platform to weaken the "productivity paradoxon", which states that higher degrees of efficiency traditionally require investment commitments, which reduce the strategic changeability [24]. In this context, loose-coupled manufacturing systems with modular, open linkages in networks enable additional economies of scope and diminish this paradox.

Dasu & Li presented a theoretic-mathematical model to show how switching production quantity between different plants is reducing the impacts of economic and political turbulences [25]. On this basis, the instable development of production costs, inflation, exchange rates or taxation can be optimized within a network by applying the pooling concept.

A similar theoretical concept using the real option approach was established by Meza & van der Ploeg [26]. If the cost or demand developments are not perfectly-negative correlated between different markets, the flexibility will always be increased by multinational production. Therefore, volatility has a positive impact on the calculated changeability value of multinational production systems.

The findings of the empirical articles within the literature sample support these coherences. Investigating Korean firms for a 16-year-period, Lee & Makhija found indicators that especially networks with a great and a small depth hold the highest potential to cope with economic uncertainty, namely high fluctuations in economic conditions [27]. The flexibility gain arises from additional options to cope with uncertainties of business operations by shifting production in other countries, using the pooling concept.

Chung et al. evaluated network performances in an economic crisis on the basis of 1519 manufacturing subsidiaries of 471 Japanese corporations in five Asian countries [28]. The findings support, that the global spread of production networks has a positive impact on changeability as production volume can be transferred between subsidiaries. The pooling of network resources adds benefit through the different developments of locational advantages.

Allen & Pantzalis found also a positive correlation between the width of production networks and the additional flexibility to adjust production to exogenous perturbation by the utilization of production shifts [29]. A sample of 626 multinational corporations emphasized the importance of different countries in which a network holds operations.

Another aspect of the pooling concept of global networks is pointed out by Belderbos & Zou [30]. Analyzing Japanese manufacturing enterprises in nine Asian countries during the years before and meanwhile the financial crisis in Asia under the flexibility perspective, findings indicate that multinational networks are used to respond to labor cost changes by production shifts.

Using a stochastic model, Francas & Minner determined a positive correlation between decentralized network structures and success in differentiated niche markets [31]. As manufacturing is dedicated to separate factories, switching options are encouraged similar to the theoretical concept of resource pooling. The authors identified the swift from mass markets to niche markets as a catalyst for production network structures.

Fisch & Zschoche operated a panel study in the EU, which indicated that production shifts increase flexibility by forming an opportunity to transfer resources across borders through a multinational network [32]. Therefore, the costs of operation under uncertainty are reduced, especially for labor intensive manufacturing, which benefits strongly from labor cost arbitrage.

The articles on production networks as an agility enabler for technology-based volatility focus on robust product launches and efficient value creation within industries of unforeseeable product life cycles, which is especially relevant for the production strategy of resource exploration.
Beginning with the conceptual articles, Gulati stated, that networks form a strategic option to overcome challenges of matching a “firm’s existing competence and the availability of new opportunities” [33]. Production networks hold a certain potential to access additional resources, which is especially relevant in changeovers between product generations, where resource requirements change rapidly.

Kulkarni et al. analyzed two different network strategies: the product plant and the process plant network strategy, which indicate low respectively high levels of process consolidation [34]. They identified the potential of process plant networks, which consolidate process-relevant activities as an enabler for higher economies of scale and risk-reducing structures. Beyond that, this allying of resources leads to a reduction of supply-side risks and production downtimes using the network slack capability of the network to substitute critical parts, processes or employees. This is especially relevant in innovative industries, where no standardized components occur.

Based on a multiple case study, Shi evaluated the benefits from multinational networks as a way to take “full advantage of the local resources” [35]. Besides picking the “most advantageous areas” in terms of cost optimization, the supply-risk of critical input material is reduced by partners of different national characteristics, which increases the adaptability of the overall purchasing volume.

Using a case-based field study, Colotla et al. established a factory-network capability matrix to manage networks in volatile environments [19]. As the capabilities on network level increase, so do information processes and innovation on factory level. In doing so, the production network supports its members to take advantage of the exploration strategy.

Stuart stated that the allying concept is highly useful under the innovation perspective [36]. As “a portfolio of alliances consisting of ties to organizations in a variety of different market niches” the production network is more valuable than a similar portfolio of alliances containing firms in the same or similar market niches. Under this perspective the allying concept gives access to relationships and capabilities to increase innovating performance.

Rothaermel executed an empirical study on biotechnology firms to discover that complementary assets can leverage the exploration strategy [37]. Production networks act as an enabler for allying cross-corporate resources, which facilitate technology shifts and increasing the performance and flexibility of the network partners holding complementary competences to support turbulent phases of product launches.

5. Discussion

Despite the fact, that the 18 academic articles considered in this paper differ widely in terms of their field of research and their research methods, the results in terms of the examined research question are quite homogenous. The articles on market-based volatility state consistently, that production networks benefit from resource pooling as an agility enabling concept to meet these turbulences. The conceptual papers highlight the production shifting options and the global real option perspective based on resource pooling, which results in less utilization risks, multiple routing and the declining influence of (local) economic and political factors [19,21-32]. The empirical studies underpin these results by presenting case studies on production shifts favored by pooling resources to respond to market and cost changes [27-32]. This seems evident, as market volatility is reduced by the consolidation of companies to form production networks in order to shape their competitive market.

In contrast, the papers on technology-based volatility indicate the advantages of the agility enabling concept based on resource allying [33-37]. In line with the blue ocean strategy, direct competition between manufacturing capacities becomes less relevant, if companies intending to entry new markets [38]. Therefore, production networks which ally their resources can benefit from accessing additional resources to compensate individual weaknesses as illustrated in the relational view. As higher degrees of freedom within the distribution of value creation are acquired within production networks, new innovations are supported by complementary assets, additional courses for operation and slack resources to bundle capacity in order to facilitate robust production processes.

For the sake of completeness, it should be added, that the references for technology-based volatility are numerically weaker. A possible explanation for this constellation is this paper’s focus on manufacturing systems. Therefore, some articles addressing technology-based volatility including communication skills and knowledge sharing within networks were excluded. Although these approaches represent an important research field in technology-based volatility, these were not relevant under the manufacturing aspect.

6. Contribution, limitations and implications for further research

The objective of this paper was to investigate the impact of production networks and their configurations on market- respectively technology-based volatility. The systematic selection and analysis of 18 articles in 13 peer-reviewed journals revealed the significance of the two different agility enabling concepts in production networks to meet different types of volatility. The major contribution of this paper is the underpinning of the strong relevance between the environmental setting of production networks and its configuration. This is displayed by the specification of different configurational designs in networks to address...
opposed volatility indicators in line with the exploitation and exploration of manufacturing resources.

When interpreting the results, the following limitations should be considered: 47% of the analyzed articles within the literature sample were conceptual papers, which derives from the abstract research object. Therefore, the applicability within single industries facing strong market- as well as technology-based volatility need to be further investigated. The inclusion of more empirical founded papers, especially with an industry-specific differentiation seems promising to deepen the findings. Another limitation is the restriction on articles in peer-reviewed journals. This may be justified by different reasons specified in chapter three; however the time-consuming feedback and publication times in top-tier journals need to be considered, especially as the organizational structure of the production network is a rapidly developing area of research.

An interesting platform for further research may arise from the holistic approach of combining the agility enabling concepts of pooling and allying manufacturing resources and the findings on configurational indicators as established above in a multistage process. This integrated agility approach on configurational designs of production networks combined with a performance measurement system to assess and manage network agility in accordance to its specific environmental setting seems promising to reveal additional insights in the operation mode of production networks.

References