Triadic relationships in New Product Development: contingent factors and implications for performance

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Abstract: Buyer-supplier relationships in New Product Development (NPD) has been intensively studied in literature (e.g. Johnsen, 2009), with a special attention on how to integrate suppliers in NPD in product modularity contexts (Pero et al., 2010). Recent studies are demonstrating that researchers should move beyond, to consider the triad buyer–supplier–supplier (B-S-S) (Choi and Wu, 2009). However, triads are still unexplored, specifically in product modularity contexts. Therefore, this paper aims to explore the influence of a set of contingency variables (frequency of component technological change, frequency of architectural innovation, type of purchase, product complexity, NPD frequency, product modularity level) on the configuration of the triad B-S-S, along with the impact on performance, in a product modularity context. A B-S-S configuration is described by the relationship in place during NPD among the buyer and each supplier, and the one in place among suppliers. Relationship between buyer and supplier can range from arm's length to full collaboration, while suppliers can co-exist or collaborate, in line with Choi and Wu (2009). Thirteen explorative case studies have been performed in medium-small sized Italian companies in the electronics industry. Results show that some companies are encouraging collaborative relationships between suppliers, except in the case where arm's length relationships are in place between the buyer and both suppliers. Moreover, results support existing literature results on the benefits for the buyer to establish a collaborative relationship with its suppliers, and highlight how fostering a cooperation between suppliers may improve the performance of the final product. Finally, preliminary results suggest that dynamic and innovative contexts may call for collaborative triads, as well as that high levels of product modularity lead to collaborative configurations.

Keywords: Triadic relationships; Buyer-Supplier-Supplier; Configuration; Product Modularity; NPD

1. Introduction

Product modularization is a product design strategy used by manufacturers to increase product variety without seriously affecting production costs (Salvador et al., 2002; Starr, 1965). Through a modular approach, it is possible to standardize product components and interchange modules with a short lead time (Ulrich, 1995). Properly combining decisions on modular product design and supply chain design improves supply chain performance (Pero et al. 2010; Fine, 1998). Academic literature on product modularization focuses its attention on dyadic relationships, representing the relational dynamics between one buyer and one supplier. Advanced studies are demonstrating that the buyer–supplier relationship context should move beyond the traditional dyadic context and begin to consider complex configurations, such as triadic relationships. Triadic relationships refer to the relational dynamic occurring between the buyer, two suppliers and between those two suppliers. Despite this trend in the academic literature, little is known on this topic when product modularity is at stake. Therefore, the objective of this study is to analyse triadic configurations in a modularity environment, taking into consideration the influence of some contingency variables on the relationship in order to define the impact on the supply chain performances.

2. Research background

In a Systematic Literature Review (SLR) approach, a preliminary research including the keywords "*modularity", "supply chain", "procurement"* and *"environment"* has been conducted. Based on a classification on macro topics, a point of interest emerged: product modularity and buyer-supplier relationship. As stated by Howard and Squire (2007) and Caridi et al. (2012), the academic literature presents two conflicting views regarding modularization and supplier relationships. The introduction of modularization suggests that buyer and supplier firms should move towards greater collaboration in order to co-develop products and hence reduce interface constraints (Hsuan, 1999; Hsuan-Mikkola, 2003). Conversely, the standardisation of interfaces due to the effects of modularization suggests that buyer firms could effectively introduce a "black box" approach, holding suppliers at arm's-length (Muffatto, 1999). The second step of the SLR was the research on web databases using the keywords "*supplier relationship*" with "*modularity*", "*modularization*", "*modular*" and "*module*". The procedure followed to select the papers was to eliminate the duplicates, discard the articles out-of-topic and, as a last step, read the remaining articles. This procedure led to an amount of 9 papers. The successive phase was to examine the references and the papers citing the 9 articles previously included. After an elimination phase similar to the previous one, 21 papers were selected. The last stage of the literature review was the synthesis and the analysis of data and insights coming from the articles. The quotes and the extracts from all the papers were gathered, with the objective to build a structured framework of the literature. Then, the extracts were grouped based on three main topics: influencing factors, moderating/mediating variables and type of relationship. This analysis led to the definition of a framework of the literature: as represented in Figure 1. The type of buyer-supplier relationship can have direct or indirect effects, through intermediate factors, on the product's KPIs. Product modularity by itself can also have direct impact on the KPIs, independently on the relationship.

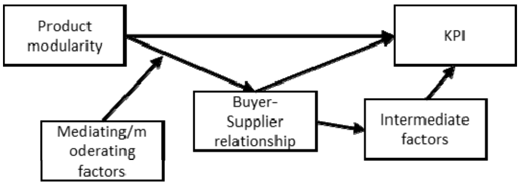

Figure 1. Structured framework for the literature

2.1 Gaps identification

T **Figure 1. Structured framework of the literature**
the link between the initial context, the type of relationship and the impact on the KPIs. Although, the articles found were either focused on the highest level of detail of a relationship – the dyadic case (Howard and Squire 2007, Hoetker et al. 2007, Hsuan 1999) – or on the lowest level of detail – the whole supply chain configuration (Lau et al. 2010, Lau and Yam 2005, Doran 2003). The subject that is not properly studied is the case of triadic relationships. Olsen and Ellram (1997), Smith and Laage-Hellman (1992) have proposed expanding the dyadic buyer–supplier relationship studies to a triadic context, where buyer–supplier–supplier relational dynamics can be considered**.** Cost, time, and competitive pressures have in fact forced suppliers into intricate interdependencies between one another resulting in a complex flow of information, materials and capital, or lack thereof. Consequently, buyers as well as suppliers need to recognize the complexity engendered by this environment in order to manage these relationships effectively (Choi et al. 2002). To verify the presence of researches about triads in a context of product modularity, a second systematic literature review was necessary, leading to the analysis of 9 papers.

3. Research scope

The result of the analysis of the articles coming from the second literature review was that a structured study of triadic relationships in a product modularity context has not been conducted yet. Therefore, the objective of this paper is to determine the impact of product modularity and the influence of the contingency variables on the triadic configurations. Subsequently, it is important to study how the different configurations affect the performances of the final product. To this aim, the following research questions (RQs) have been defined:

RQ1: (in a product modularity context) what are the different buyer-supplier-supplier (B-S-S) configurations?

As a result of the literature review, different contingency factors such as product complexity (Hsuan, 2003, Muffatto, 1999) and component technological change (Lau and Yam, 2005, Furlan et al., 2014) have an impact on the buyer-supplier relationship. It is therefore significant to study what contingency factors influence the development of triads in a product modularity context:

RQ2a: (in a product modularity context) what are the contingency variables that influence the B-S-S configurations?

It is fundamental to analyse the impact of these contingency factors on the triads. Moreover, it appears that diverse levels of product modularity lead to the creation of different dynamics among the actors of the supply chain (Lau and Yam, 2005, Howard and Squire, 2007). Thus, it is also important to understand the impact of the level of product modularity on the configurations.

RQ2b: (in a product modularity context) how do the contingency variables and the level of product modularity influence the B-S-S configurations?

Finally, the buyer-supplier relationships have an impact on the performances of the final product in terms of costs, time and quality (Lau and Yam, 2005, Ragatz et al. 2002, Muffatto, 1999). The objective is to understand if the B-S-S configurations have an influence as well on these performances and what is their magnitude:

RQ3: (in a product modularity context) how do the B-S-S configurations impact on KPIs?

Figure 2 depicts the research framework studied in the present research. To describe the framework, a set of constructs has been defined: product modularity, buyer-supplier-supplier relationship, contingency variables and KPIs.

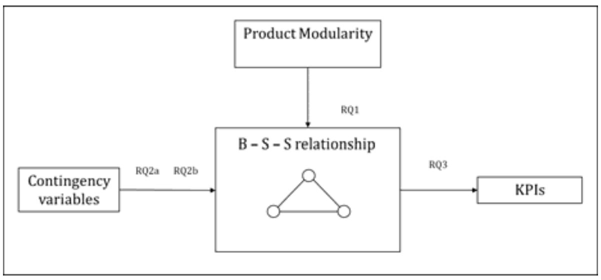

Figure 2. Adopted research framework

3.1 Product modularity

According to Ulrich (1995), a product has a modular architecture when it is constituted from the association of different sub-assemblies (modules) characterized by their autonomous and independent nature. The literature identifies three core modularity aspects (Parker 2010):

1. Functional binding, (Baldwin and Clark 1997, Ulrich 1995) that allows to add functions to a product by adding components;
2. Interface standardization, that refers to the common mechanisms for interaction among complementary product components of a system (Vickery et al. 2015);
3. Decomposability, which defines how easily a system can be separated into its various components, making the swapping practical and reconfigure the overall system (Antonio et al. 2007, Worren et al. 2002).

3.2 Buyer-supplier-supplier configurations

Triadic relationships are built upon the intersection of two different components: buyer-supplier relationships and supplier-supplier relationships. Buyer–supplier relationships can vary from a cooperative relationship (strategic partnership) to the arm's length (competitive) relationship (MacNeil 1974; Choi et al 2001). In a cooperative relationship, two companies have a long-term commitment and share common goals (Choi and Liker 1995; Axelrod 1997). By contrast, in competitive buyer–supplier relationships the buyer often operates based on a short-term relationship orientation and the supplier is wary of potential exploitations (Axelrod 1997). As regards supplier-supplier relationship, Choi et al. (2002) described three archetypes. In a coexisting supplier–supplier relationship, the suppliers keep each other at distance without any direct line of communication. The buying firm interacts with each individual supplier independently and serves as a router of information exchange between suppliers. In a cooperative supplier-supplier relationship, the suppliers work together closely, exchange ideas, and may engage in common projects. Finally, Brandenburger and Nalebuff (1996) defined a coopetitive supplier-supplier relationship as "a concomitantly competing and cooperating relationship". For the purpose of this research, the analysis will be centred only on the cases of coexisting and cooperative suppliers without considering the coopetitive configurations. Triadic configurations can take place among the buyer, downstream vendor, and upstream supplier or among a buyer and two suppliers (Choi and Wu, 2009). Wu et al. (2010) sustained that the buyer, because of its business interest, is motivated to influence the nature of the relationship between the suppliers. Through systematic case analysis, Wu and Choi (2005) found that interactions between suppliers, or lack thereof, would eventually affect the performance of the buyer's supply chain operations.

3.3 Contingency factors

Frequency of component technological change: it is defined as "the rate of change of the product and process technologies underlying a given component within an existing product architecture" (Furlan et al.2014). *Frequency of architectural innovation*: modifications in how subsystems are linked together (Sanchez and Mahoney, 1996). *Type of purchase*: the supply items can be classified into four categories (strategic, leverage, bottleneck, non-critical), based on two factors: profit impact and supply risk (Kraljic, 1983). *Product complexity*: described as the presence of many different parts, linked in a way that make an object difficult to fully understand (Kauffman 1995, Simon 1962). *Frequency of New Product Development (NPD) process*: the overall process of strategy, concept generation, marketing plan creation and evaluation, and commercialization of a new product (Kahn 2005).

3.4 KPIs

Quality: Crosby (1972) focuses on the quality of conformance, defined as the "level of effectiveness of the design and production functions in respecting the product manufacturing requirements and process specifications, while meeting process control limits, product tolerances, and production targets". *Time*: defined through the order lead-time and NPD lead time. The first refers to the time which elapses between the receipt of the customer's order and the delivery of the goods. NPD lead time considers how long it takes a company to design a new product, design the manufacturing process, and become ready to manufacture the product. *Costs*: composed by total cost of acquisition, defined as the net price plus other costs needed to purchase the item, manufacturing cost, that is the total cost of manufacturing, including labour, maintenance, and overhead, and inventory cost that is associated with held inventory.

4. Research methodology

Given the subject of the study and the research questions emerged from the literature, the most suitable research methodology is the case study. A key difference between a single case study and a multiple case study is that in the last mentioned, the researchers understand the differences and the similarities between the cases (Baxter and Jack, 2008; Stake, 1995). This research faces a multitude of possible triadic configurations; thus, the multiple case study is the best approach to examine this phenomenon. Industrial electronics has been chosen as the sector to be analysed for two reasons: first, electronic products are fitted to be designed in a modular way, and, second, since it is growing fast and its businesses are diffused and consolidated in the Italian industrial landscape, in particular in Northern Italy. To select the cases, Yin (1994)'s methodology was adopted. First, the study established the research boundary according to the research questions. The case companies were selected after ensuring they were of interest in this area and persons knowledgeable about the case were accessible. The modalities used to perform the interviews were mainly three: face-to-face in the facilities of the firms, via telephone call or via Skype call, depending on the purchasing manager's preference. Data were collected through a structured questionnaire, and an interview procedure was used as a guideline throughout all the case studies. Moreover, some secondary sources such as the companies' websites have been exploited to integrate the data gathered during the interviews; plant visits were arranged when possible, in order to personally meet the managers and to see the products analysed. 13 case studies have been performed. Table 1 summarizes the main information regarding the companies analysed.

	Size (n.employees)	Product	Product modularity	B-S1	B-S2	S1-S2
Case 1	Small (9)	Intercom	M-H	A	A	COEX
Case 2	Small (28)	Automatic driving system	M-H	C	C	COOP
Case 3	Small (11)	Manoeuvring panel	M	C	A	COEX
Case 4	Small (40)	Diagnostic instrument	M-H	C	C	COEX
Case 5	Small (9)	Testing machine	H	C	C	COOP
Case 6	Small (9)	Voltage transformer	M-H	C	C	COOP
Case 7	Small (5)	PXI	M-L	C	A	COEX
Case 8	Medium (80)	Machine panel	M-L	A	C	COOP
Case 9	Small (6)	Electrical panel	H	A	A	COEX
Case 10	Small (9)	Industrial camera	M-H	C	A	COOP
Case 11	Medium (60)	Electrical panel	M	A	C	COEX
Case 12	Medium (67)	Industrial PC	M	A	C	COEX
Case 13	Small (15)	Overvoltage arrester	M-H	C	C	COEX

H: High product modularity
M: Medium product modularity
L: Low product modularity

A: Arm's length relationship
C: Collaborative relationship
COEX: Coexisting relationship
COOP: Cooperative relationship

Table 1. Companies information

5. Findings

In this section, the results emerged from the interviews are discussed in depth.

5.1 RQ1: what are the different B-S-S configurations?

Based on the interviews performed, the B-S-S configurations emerged in a product modularity environment are the number 1, 2, 3, 4 and 5 as highlighted in Figure 3.

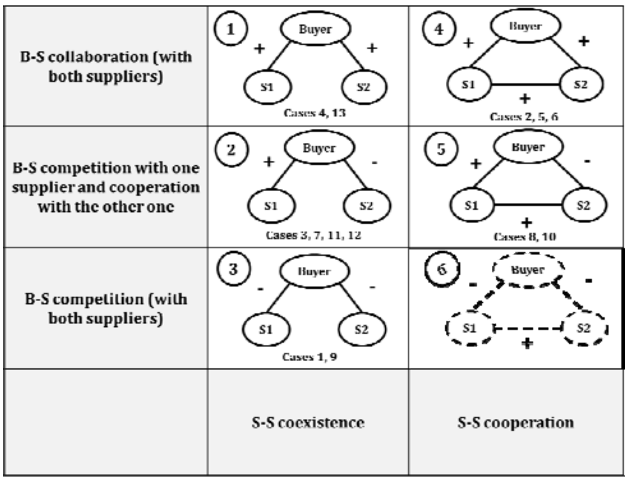

Figure 3. Triadic configurations emerged

The configurations 1, 2 and 3 are characterized by the coexistence between the two suppliers. There are two main motivations that could lead the buyer to not foster a relationship between the two suppliers. T*he buyer is unable*: the suppliers are not interested in forming a relationship and the buyer is not powerful enough to force them. As reported in Case 12, the buyer interacts with a small company and a multinational firm. It would be really difficult for the buyer to encourage any type of interaction since he does not have the power to impose a decision regarding the relationship on the multinational company. *The buyer is not interested*: the buyer does not see any benefit in fostering a relationship between the suppliers. As emerged in Case 11, if there were any advantages, such as discounts for purchasing larger amounts of raw materials or common clients to serve with a shared logistic service, the buyer would have fostered the relationship between the suppliers to exploit those synergies. Another motivation is that the buyer specifically chooses to not make the suppliers communicate to preserve the technological know how about its own products, as witnessed in Case 13, where the buyer stated that: "while developing a new product, the company's policy is to keep a strict control of the process and a high level of secrecy; therefore, we prefer to be the only intermediary between the suppliers". Configurations 4, 5 and 6 reported in Figure 5 are characterized by a cooperative relationship between the two suppliers. Configuration 4 is characterized by a total collaborative relationship within the triad; Case 5 witnesses the enormous performance advantages deriving from this configuration. Configuration number 5 instead is characterized by a mixed B-S relationship (one arm's length and one collaborative supplier) with cooperative suppliers. Cases 8 and 10 provide evidences of this triad; the buyer, by leveraging on the arm's length relationship and the collaboration within the suppliers, gains multiple advantages regarding the KPIs analysed. Configuration number 6, as expected, has not been experienced during the interviews due to its instable nature. In fact, the buyer would suffer in such situation since the two suppliers could collude together against the buyer itself. Therefore, this situation leads to a more stable triad, which is represented by configuration number 5.

5.2 RQ2a: what are the contingency variables that influence the B-S-S configurations?

In a product modularity environment, frequency of component technological change, frequency of architectural innovation, product complexity, frequency of NPD and the level of product modularity influence the triadic configurations. The type of purchase is the only factor that seems to not influence the relationships. During the interviews, two factors not considered in the study emerged: the supplier size and the presence of synergies. Only the first one has an impact on the definition of triadic configurations, as reported in Case 1: "It is not possible to think about a collaboration with these suppliers since they are multinationals; we are just a small firm and we can't define the type of relationship".

5.3 RQ2b: how do the contingency variables and the level of product modularity influence the B-S-S configurations?

In cases of high frequency of component technological change, both the B-S and S-S relationships are pushed towards a collaboration. Regarding the B-S, the buyer wants to keep the same suppliers and collaborate with them over time to guarantee quality and continuity of the service. The benefits deriving from a dyadic collaboration can be easily expanded by fostering a good relationship between the suppliers. Even in a case of low frequency of component innovation, there is evidence about the need to collaborate to avoid incurring in issues when there is an innovation: the manager of Case 4 stated that "Even if rare, it is necessary to cope with change. To avoid incurring in issues when there is an innovation it is better to have a strict relationship with the suppliers". A high frequency of architectural innovation implies a good level of collaboration. Having a partnership with the supplier helps to keep up with the innovation, to uniform interfaces and production processes. An elevated level of architectural change implies also a collaboration within the suppliers to help the overall triad to cope with the variations in the structure of the product. In cases of a low frequency of this contingency factor, a consequence is the development of a collaboration since the stable architecture of the product allows to create long term bond with the suppliers. A collaborative behaviour has been noticed between the suppliers also in case of low architectural change: similarly, to the buyer-supplier case, the stable architecture helps the buyer to keep the suppliers linked together for a long time. As confirmed by the manager of Case 6: "Our product is not suited to frequent architectural changes, but our supplier, thanks to the collaboration, is in any case available to adopt a change". Product complexity pushes towards a collaboration due to the phenomenon of the knowledge barrier. The buyer does not have a complete knowledge about a module, mainly due to its complexity; therefore, it prefers to keep a close relationship with the suppliers, since a high level of trust is necessary. At the supplier-supplier level, a high product complexity requires a collaboration since it is easier to cope with the many issues of the design of a complex product. The presence of NPD always leads to a collaboration with the suppliers and, in case of a high frequency, also between the suppliers. In case of a low frequency of NPD, a collaboration strategy allows the buyer to keep the same suppliers for a long period and to have a good relationship with them. Also in case of high NPD frequency, the collaboration is necessary to follow the new technologies and to have trusted suppliers. As concerns the supplier-supplier relationship, there was evidence about the collaboration between the two suppliers; this case amplifies the benefits coming from the dyadic case. As witnessed by the manager of Case 10: "The collaboration with and between the suppliers is fundamental to guarantee a good quality and speed of the process". The relative size has an influence only in the case of a supplier larger than the buyer. Given the significant size difference, the buyer has a reduced bargaining power, therefore the possibilities to collaborate are slim, unless the supplier decides to establish a partnership. Regarding the supplier-supplier relationship, the results of the study demonstrate that the buyer is not able to foster the collaboration between them, due to their size. The presence of synergies has an impact only on the supplier-supplier configurations. In fact, where there is the possibility to foster a partnership between the suppliers, the buyer could evaluate the presence of synergies. If not present, the dynamic between the two suppliers is left as a coexistence. The highest levels of product modularity lead to collaborative configurations. In fact, the players collaborate in order to develop the modules and the interfaces to accommodate the production necessities of all the actors. For example, it is possible to design a product interface that supports the already existing production processes, without affecting the production costs. Cases 2, 4, 5, 6 and 13 provide evidence of this phenomenon. Case 10, instead, is slightly different since the relationship with one supplier is an arm's length. The main motivation is that the buyer wants to exploit the economic advantages deriving from the arm's length relationship with one supplier without sacrificing the benefits from their collaboration. In fact, as the manager of Case 10 stated: "We don't even interfere in the collaboration of the two suppliers as long as it provides us indirect benefits". The other cases found associate lower levels of product modularity with a mixed B-S relationship with coexisting suppliers. Since the product is less modular, the buyer can afford to exploit his leverage on the suppliers, therefore lowering the overall level of collaboration.

5.4 RQ3: how do the B-S-S configurations impact on KPIs?

The triad corresponding to B-S collaboration with coexisting suppliers has an extremely positive impact on all the KPIs considered. The partnership with the suppliers leads to an improvement of the quality of conformance since immediate communication allows to solve production issues quickly and improve the characteristics of the product. This triad allows to obtain preferential channels effectively improving the order cycle time. Furthermore, the unforeseen events, such as delays in the delivery process, are managed with a higher priority. Due to the union of the know-how between the buyer and the supplier, the NPD lead time is quicker, and the overall process has a higher quality. The acquisition costs decrease: the buyer informs the supplier about his future purchases obtaining greater discounts. The manufacturing costs are positively influenced since the buyer and the supplier agree to larger production lots allowing costs reduction in the production process. Regarding the inventory costs, the supplier is available to keep the inventory inside his own facility. The fully collaborative triad presents similar characteristics to the B-S-S configuration described above but, due to the collaboration between the two suppliers, the positive effects of a buyer-supplier collaboration are emphasized. The triad characterized by cooperative suppliers and collaboration with one supplier and arm's length with the other presents a good impact in terms of quality and time performance, mainly due to the collaboration between the suppliers. The triadic configuration characterized by the mixed relationship with coexisting suppliers presents the positive aspects connected to collaboration, while the arm's length relationship causes some disadvantages like longer delivery times and higher inventory costs.

6. Conclusions

Collaborative triads are the most advantageous configurations in terms of the impact on the KPIs considered. In fact, they present the highest advantages for the buyer bringing significant improvement to all the three dimensions considered. Meanwhile, the triad with a mixed B-S relationship with cooperative suppliers is less advantageous considering the effects on the KPIs, but it could be a good strategy for the buyer to form this triad to exploit its advantages and at the same time putting small effort in maintaining it. Introducing a collaborative behaviour with at least one supplier provides KPI improvements compared to the baseline of the arm's length case. Moreover, moving from a dyadic configuration to a triadic one appears to be advantageous for the buyer. The fundamental managerial implication is that the players of the supply chain should move beyond a dyadic approach and start thinking in triadic terms in order to improve the overall product performances. In terms of research limitations, a higher number of interviews might have strengthened the findings of this study. The choice of the industrial electronics sector could be a limitation for the generalization of the model provided since it is possible that other sectors could be dominated by different relational dynamics. In terms of further research. a quantitative study conducted through a survey could be useful to better understand the correlation between the variables selected in the study. Moreover, it could be interesting to reproduce a similar research in other industrial sectors to understand if there are no differences between different industries. In order to expand and increase the robustness of this work, it could be useful to consider other contingency variables that could impact the formation of triadic relationships.

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