

ANALYSIS OF TRUST VIA THE INTERRELATIONS BETWEEN INTERMEDIARIES IN A DECENTRALISED SUPPLY CHAIN

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Abstract: This article looks at the role of middleman relationships in a decentralized supply chain, considering a three-element structure consisting of an independent supplier, a distributor, and a producer. We study a model based on game theory that allows the analysis of the coordination of the three links, which evaluates qualitative criteria in their supply relationships, distribution, and reception of their operating preferences. The objective of the research is the construction of trust by analyzing the interrelationships of the three links for their consolidation, or not of the supply chain, using the Nash equilibrium, which allows summarizing satisfaction and loyalty throughout the supply chain. The set of Nash equilibria reflects that achieving satisfaction in the interrelationships between them is the main strategy to be followed by companies seeking to promote coordination within their operations. At the same time, we observe that only one agent is sufficient to maintain the flow of materials, i.e., the problem of the free-rider arises between us. In this study, five different equilibria are obtained, of which in four the supply flow continues within the chain, and in one equilibrium the relationship fails.

1 Introduction

The globalization of many industries has strengthened the competition that companies live in their markets, making necessary the improvement of the supply chain's management [1]. Nowadays, production processes take place in different places which implies the involvement of different agents, even from different countries, within the supply chain; this makes necessary to revisit the selection of partners. The literature recognizes the importance of intermediaries to satisfy the requirements from suppliers and producers costumers [2]. So, the benefit of a downstream company relies on the capacity of suppliers and intermediaries to satisfy requisitions. Hence, many companies invest in the development of better relationships with their elements in the supply chain to boost their overall performance and to increase the competitiveness level of the supply chain [3].

Reaching an efficient performance of the supply chain is not an easy task given the interaction of agents with specific objectives. That is to say, there are multiple

decision-makers that control the behavior of a supply chain, some of them may have interests in opposition with the objectives of other agents [4]. For example, manufacturers prefer to produce in large batches to reduce installation costs. This increases the number of finished products in inventory, which will eventually increase costs, contradicting the original motivation for such a strategy [5].

It is important to note that member interactions follow the structure of the supply chain. Given the importance of intermediaries, this focuses in the analysis of a decentralized supply chain, which is a structure where agents have to make multiple decisions to improve their interrelationships [6]. On the other hand, Within a centralized supply chain, there is only one decision-maker that controls the activities within the supply chain. The first situation results in local improvement of the interrelations between the members or agents (supplier, distributor, producer), while the centralized system leads to a global development [7]. Our analysis models the decentralised interaction through a game theoretical approach where

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coordination in the activities between the supplier, the intermediary and the producer contributes to a better location of facilities to fulfil with on-time deliveries.

We analyse a supply chain with three agents: a supplier, an intermediary, and a producer. Considering a simple framework, we assume that producer and supplier may choose between to stay, or not, in the supply chain. So, our equilibrium analysis allows us to identify those scenarios of consolidation, or breaking-up, of the supply chain. Also, we show that the set of equilibria serve to determine the presence, or absence, of trust within the supply chain. Later, we argue the implications of such a factor.

The study of how to generate trust within a supply chain is not new since it is a mechanism to improve the coordination between suppliers, distributors, and producers. Nowadays, the globalization of production processes requires the generation of trust for the efficient progress of supply chain members' activities. It is worth to mention that trust acts as a prerequisite to improving the performance of the three most essential processes in the management of the chain: a) flows of materials, b) financial flows and c) information flows. Hence, trust is a precedent to achieve cost reduction via the management. However, it is common that intermediaries do not adequately fulfil their activities generating distrust, which motivates the establishment of positive/negative incentives to induce the adoption of strategies or the fulfilment of specific objectives. We recall that trust generation is crucial since new challenges that supply chains face in the globalization of processes [8].

Our motivation comes from the manufacturing sector where inventory management and on-time fulfilment of customers' requisition may decrease companies' benefits. In [9,10] provide empirical evidence about the impact of intermediaries' actions on the benefits of their clients. Also, they observe that trust is the consequence of the frequency and long-term interactions. So, there is an opportunity area to generate confidence within supply chains. In this sense, game theoretical models provide useful insights into the designing of contracts that establish punishments to those that deviate from a desirable behaviour [1,11].

This paper focuses on analyzing a three-link supply chain through a game theoretical approach. We define the relationship between a supplier, an intermediary and a producer based on the fulfilment of each agent obligations to study the effect of trust in the consolidation or disaggregation of the supply chain, we can exemplify the following, we construct the agents' preferences considering the negative impact of non-compliance over agents' benefits. Moreover, we present the Nash equilibrium analysis in a case where agents only can win, lose or remain indifferent. The equilibria set is not a singleton; non-surprisingly, the disaggregation of the supply chain is an equilibrium, but there are equilibria where the supply chain

stands when a single member copes with his responsibilities.

The article is presented in the following order, Section 2 presents the state of the art on the importance of trust within the supply chain and how they interact between suppliers, intermediaries and producers has been analyzed it. So, in section 3 we present a game theoretical that summarizes the possible scenarios that our supply chain faces. Section 4 presents the equilibrium analysis, and in section 5 the conclusions reached according to the Nash equilibrium are presented.

2 Literature review

Our article is closely related to analyzing the impact of intermediaries in the success of supply chain activities. In [12], Vieira et al. investigate how the cultural differences between 338 processing plants, in Asia and occidental countries, impact their relationships with intermediaries and the influence of such impact on suppliers' activities. They use structural models to measure the presence or absence of trust. In general, processing plants differences are crucial for the development of a supply chain because their decisions contribute to modify the behavior of previous links in the supply chain. The empirical evidence shows that Asian companies tend to trust more on each other than western companies, [13,14]. In a similar work, [15], MacDuffie, observes that processing plants are the first to punish since intermediaries often forget to evaluate the quality of suppliers' product. It is usual that that quality, from providers products, is taken for granted by the intermediary. However, such negligence generates negative incentives for the supplier activities. That is to say; suppliers have incentives to low the quality of their products since other members of the supply do not implement a complete assessment of their activities.

In recent years, the presence of conflicting objectives within a supply chain, from its participants, indicates that game theory is an appealing methodology to model the generation and impact of trust [16]. In this type of analysis, the structure of the supply chain is essential. In [17], Charvet et al. observe that the number of links in the supply chain has a different impact on the development of the supply chain since each link has specific objectives with different consequences for the other elements of the supply chain. So, the collaboration is necessary to reach a common purpose. However, a collaborative behavior requires different incentives [18].

The most straightforward supply chain, a producer, and a supplier is defined as a centralized structure since the producer also acts as an intermediary to attend final customers. Our paper develops a decentralised supply chain with the presence of an intermediary, who is independent of the decisions that take the producer and the supplier. Also, a decentralised supply chain is often called a three-tier supply chain. In [19], Huang, Huang and Newman analyze the equilibrium interaction of such kind of supply chain following a dynamic approach. They show

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that inventory levels become a coordination problem since the capacity of some agents to set prices. The coordination analysis motivates non-cooperative [20] Zhao et al. and cooperative approaches [21] Huang and Li.

3 Methodology

We consider a decentralised supply chain with the following players: a supplier, a distributor, and a producer. First, we consider a simultaneous game with incomplete information among these three agents. In this interaction, the supplier produces raw material that is used by the producer. The communication between these two agents relies on the distributor intervention. The central aim of our model is to analyse the consolidation or to break up, of the supply chain. Below, we describe the action that each can take in this supply chain.

Note that suppliers take care of raw material's quality, while the distributor is in charge of doing the delivery of the raw material. So, we consider that supplier may supply

(D), or not (ND), the good. Also, it is important to recall that distributor's reputation depends on how the producer evaluates him. So, distributor's actions are the four possible combinations between Receive (R), Not Receive (NR), Give (G) and Not Give (NG), i.e., distributor's actions are (R, G), (R, NG), (NR, G) AND (NR, NG). Implicitly, the action (NR, G) assumes that distributor can satisfy producers' requisition using his inventory. Also, the action (R, NG) represents a situation where the distributor wants to increase his inventory levels by not fulfilling the producer's requisition. This behaviour is not unusual since distributor may desire to increase the cost by generating scarcity. Finally, given the features of raw material and distribution service, the producer chooses to continue (S), or not (O), with her relationship with this intermediary. The payoff of each supply chain member depends on the other actions. Table 1 summarises all the possible scenarios that result from the interaction between the producer, the distributor and the supplier.

Table 1 Payments matrix of the supplier, distributor, and producer

P R O D U C E R	DISTRIBUTOR													S U P P L I E R	
		Receive and Give (R, D)			Receive and Not Give (R, ND)			Do not Receive and Give (NR, D)			Do Not Receive and Do not Give (NR, ND)				
	Continue (S)	X	A	M	H	I	J	C	LL	E	P	Q	U		Supplying (D)
		Y	B	N	K	L	Ñ	F	G	Z	T	W	V	Not supplying (ND)	
Choice of another (O)	X'	A'	M'	H'	I'	J'	C'	LL'	E'	P'	Q'	U'	Supplying (D)		
	Y'	B'	N'	K'	L'	Ñ'	F'	G'	Z'	T'	W'	V'	Not supplying (ND)		

Below, we discuss the relationship between the payoffs, concerning players preferences.

Producer Payments

- **X > X'**. Note that, in this case, choosing another supply chain is unnecessary since the distributor and the supplier fulfil their obligations, (R, D) and D respectively.
- **Y > Y'**. The producer prefers to stay in the supply chain since the distributor fulfils with his requisitions.
- **X > Y**. Although the first link of the supply chain does not fulfil with their obligations, the supplier chooses ND, and the distributor satisfies the producer's requisition.
- **H > H'**. In this case, it is not necessary to choose another supply chain that can meet its obligations, D and even though the distributor is not complying with Do not Give (R, ND), respectively.

- **K > K'**. The producer prefers to remain in the supply chain and even though the distributor is not supplying the product.
- **H > K**. The second link in the supply chain does not fulfil its obligations, the distributor decides not to give ND, does not satisfy the request of the producer. However, the producer decides to continue trusting because the supplier did comply with the demand to give D.
- **C > C'**. Keep in mind that, in this case, it is not necessary to choose another supply chain since the distributor fulfils half of his obligations by not receiving (NR, D) and giving, the supplier fulfils his obligations to give D.
- **F > F'**. The producer prefers to remain in the supply chain since the distributor only complies with giving (NR, D) and satisfying his requisitions.
- **C = F**. Although the first link in the supply chain complies with its obligations, the supplier chooses to give D, but the distributor is not receiving (NR) the

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goods. So, the D is indifferent between the action that P chooses.

- **P > P'**. In this case, it is not necessary to choose another supply chain since the supplier fulfils his obligations, even though the distributor does not comply with his activities.
- **T = T'**. The producer prefers to remain in the supply chain and even though the distributor and supplier do not fulfil their obligations respectively.
- **P > T**. Note that the second link in the supply chain does not meet its obligations, the distributor decides not to receive and not give (NR, ND), and the supplier did comply with the demand to give D.

Distributor Payments

- **A > A'**. Because the distributor and the supplier fulfil obligations, (R, D) and D, respectively, in this case, it is not necessary to choose another supply chain.
- **B > B'**. The distributor is complying with the producer's requests, which is why he prefers to remain in the supply chain.
A > B. The distributor, satisfies the producer's request, although the first link in the supply chain does not fulfil its obligations, because one of the two suppliers chooses ND.
- **I > I'**. The distributor decides to receive and not give (R, ND) falling into a breach of obligations and the supplier fulfils the supplies giving D, in this particular case, the producer chooses to continue the supply chain due to the trust he still has.
L > L'. The distributor and supplier are not complying with the producer's requisitions, which is why the last opportunity for both are presented. Also, in this situation, he has no more supply options, so he remains in the chain.
I > L. The second link does not fulfil its obligations, the distributor decides not to give ND, not satisfying the request of the producer. However, the producer decides to continue trusting because the supplier did meet the demand to give D.
- **D > D'**. Keep in mind that, in this case, it is not necessary to choose another supply chain since the distributor complies with half of his obligations by not receiving and giving (NR, D), the supplier fulfils his obligations to give D.
G > G'. The distributor only complies with giving (NR, D) and satisfying the producer's requests to remain in the supply chain.
- **D > G**. Although the first link in the supply chain fulfils its obligations, the supplier chooses to give D, and the distributor is not receiving (NR), and only satisfies the request of the producer.

- **Q > Q'**. In this case, the distributor does not fulfil its obligations, and because the supplier fulfils his D obligations, it is not necessary to choose another supply chain.
- **W > W'**. The distributor and supplier do not fulfil their obligations respectively. Due to the complexity of replacing the two agents at the same time and the producer prefers to stay within the framework.
- **Q > W**. Note that the second link in the supply chain is not met, the distributor decides not to receive and does not give (NR, ND), and the supplier did comply with the request to give D. reason why the producer remains with them in the supply chain.

Supplier Payments

- **M > M'**. In this case, it is not necessary to choose another supply chain that can fulfil its obligations D, and the distributor to receive and give (R, D), respectively.
- **N > N'**. Although the supplier is not supplying the product to the distributor, the supplier, if it gives and receives the product, the producer prefers to remain in the supply chain.
- **M > N**. Keep in mind that this is the ideal case of a trust scenario because all the intermediaries in the supply chain fulfil their obligations.
- **J > J'**. Even though the supplier fulfilled his obligations, D and the distributor does not do it because he only receives and does not give (R, ND), In this case, it is not necessary to choose another supply chain, due to the effort and commitment of the supplier.
- **O > O'**. The supplier is not supplying the product to the distributor, but he gives takes. Moreover, for that reason, the producer prefers to remain in the supply chain.
- **J > O**. The supplier did comply with the demand to give D to the distributor but decides not to give ND, not fulfilling his obligations with the producer. However, although the second link in the supply chain fails to satisfy its obligations, the producer decides to remain within this supply chain.

4 Results - Example for Nash equilibrium analysis

To illustrate the game that we described in the previous section, we present (Table 2) a payoff matrix considering the values of -1, 1, and 0. If the agent wins, loses or remain indifferent in the scenario described by the corresponding strategies profile.

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Table 2 Example of intermediary payments matrix

P R O D U C E R	DISTRIBUTOR													S U P P L I E R	
		Receive and Give (R, D)			Receive and Not Give (R, ND)			Do not Receive and Give (NR, D)			Do Not Receive and Do not Give (NR, ND)				
	Continue (S)	1	1	1	1	1	1	1	0	-1	1	0	-1		Supplying (D)
		-1	-1	0	0	-1	0	0	1	0	-1	0	0	Not supplying (ND)	
	Choice of another (O)	0	0	1	-1	0	1	-1	1	-1	0	0	-1	Supplying (D)	
		-1	-1	0	0	-1	0	0	-1	0	0	0	0	Not supplying (ND)	

5 Discussion - Nash equilibrium

To know the equilibria of the payment matrix of the supplier, distributor, and producer, we calculate the best response of each player. We find five Nash equilibria in the previous game, that we discuss below.

1. (S, (R-D), D)

The producer follows (S) or continues in the supply chain because the distributor receives (R) the product and gives it (D) and the supplier starts giving (D) the raw material. This first equilibrium could be understood as the full trust between the three players as they all give and receive and continue with the same structure. This balance is considered natural because all intermediaries fulfil their activities effectively and reciprocally.

2. (O, (R-D), D)

The producer does not follow (O) or does not continue in the supply chain, although the distributor receives (R) the product and gives it (D) and the supplier starts giving (D) the raw material. In this second equilibrium, it is observed that the producer changes or do not continue in the structure of said chain, although he is receiving the product, however, if confidence is generated between the supplier and distributor considering continuing with the same structure between said players. We do not omit that the result is surprising because the first two intermediaries comply without any problems that the producer requests and he decides to change the structure of the chain together with them. However, it is a reflection of what happens in real life.

3. (S, (R-ND), D)

The producer follows (S) or continues in the supply chain because the distributor receives (R) the product, but does not give it (ND) and the supplier starts giving (D) the product. In this third equilibrium, we observe a proper interrelation of coordination between the supplier and the producer because the first decides to give the goods and the last continues with supply chain structure even though the distributor, receiving the product, does not deliver it generating an area of opportunity to improve. In the same way, this balance surprises the result or decision of the producer who decides to continue the relationship with the

distributor, due to the failure of the same, but this reflects that in reality, many processes need particular or specific distributors. Therefore, they take the attitude of imposing priorities and not coping, and for them arise for both intermediaries areas of opportunity.

4. (S, (NR-D), ND)

The producer follows (S) or continues in the supply chain because the distributor does not receive (NR) the product, but if he manages to give (D) the product and the supplier starts not giving (ND) the raw material. In this fourth equilibrium, it is observed that confidence is generated between two players: distributor and producer, even though the supplier starts poorly or with a breach, as happens in a particular case of industrial life. Alternatively, the fantastic reflection of the total commitment that the distributor has a policy not to fall into default and to wear down the relationship with his final client. In this case, the producer because the relationship he has with the supplier is a complete loss.

5. (O, (NR-ND), ND)

The producer does not follow (O) or does not continue in the supply chain, as the distributor does not receive (NR) the product and consequently does not give (ND), and the supplier starts not giving (ND) the product. In this last equilibrium reflects that the behaviour of intermediaries are natural because it is observed that there is no penalty or punishment for any player because there are breach relations between them.

6 Conclusions

Our article qualitatively analyzes the relationships of intermediate actors within a supply chain using the Nash equilibrium. The theoretical analysis of the game contributes to establishing five equilibria within a framework of actions by each of the members immersed in the said chain and how they impact its behavior and general structure.

The first equilibrium could be understood as full trust between the three players since they all give, receive, and continue with the same structure. This balance is considered natural because all intermediaries carry out their activities effectively and reciprocally. The third

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equilibrium reflects a surprising result or decision on the part of the producer who decides to continue the relationship with the distributor, despite the failure in the delivery of material from the latter, due to the particularity or specificity of his services. This gives us guidelines for the investigation of the particularities in the processes or services of the distributors and the tolerance levels of the producers to continue with the relationship. The fourth equilibrium identifies the efforts of the distributor to supply the producer even when the supplier does not comply, denoting the total commitment that the distributor has with a policy not to fall into default and wear down the relationship with its end customer.

In this way, we observe factors that exert a positive and motivating effect on trust and loyalty, as well as incentives for freeriding. In other words, although most of the studies focus on motivating aspects, our analysis identifies that the members of the offer pursue the maximum benefit by taking advantage of the trust that others place in them.

However, the second equilibrium reflects a change in the chain structure due to non-compliance by the producer, while still surprising the producer's decision, despite the distributor and supplier's compliance. However, it is a reflection of what happens in real life. Therefore, it gives way to the future qualitative and quantitative study of the reasons why a producer, despite having efficient supply services, decides to break with the supply chain structure. A five equilibrium shows the disinterest and lack of commitment on the part of the three players. This is motivated by the lack of penalty and/or punishment for the players because there are breaking relationships between them.

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