

THE ROLE OF SUPPLY CHAIN INTERDEPENDENCE IN THE SHAPING OF A REINFORCING FEEDBACK OF DISRUPTIONS

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ABSTRACT

The paper seeks to investigate whether supply chain interdependence is related to a reinforcing feedback of disruptions. In order to achieve this goal, link between the span of supply chain structure and the strength and direction of the transmission of disruptions is revealed. The theoretical framework of a reinforcing feedback of disruptions is evidenced by cross-sector findings obtained from an exploratory study carried out in European supply chains.

INTRODUCTION

The risk of adverse effects caused by certain factors may be often transferred to other links in a supply chain. It means that the negative effects of risk are extended beyond the boundaries of individual firms and thus indirectly transferred to other companies. The propagation of negative effects of risk from one company to others as a result of an indirect impact of certain risk factors may be referred to as a feedback of disruptions. However, the disruptions may be amplified while propagation bringing analogy to a reinforcing feedback process, which is the engine of growth or accelerating decline. Therefore, the transmission of amplified disruptions may be described as a reinforcing feedback.

Although the problem of a reinforcing feedback of disruptions in supply chains has not been extensively explored or well-documented in theory and practice, it may be argued that the phenomenon is associated with the complexity of supply chain structure. One of the factors of supply chain complexity is interdependence, referring to the network perspective of supply chains.

The paper seeks to investigate whether supply chain interdependence is related to a reinforcing feedback of disruptions. In order to achieve this aim, the following structure of the paper has been employed.

Following the introduction, the nature of a reinforcing feedback of disruptions is explored. Afterwards, supply chain interdependence has been explained. In the next part of the paper, the methodology of an empirical study conducted in the sample of European supply chains is revealed. The findings derived from the analysis are presented and discussed. Finally, the conclusions of the research are drawn and the implications for further empirical studies are indicated.

THE IDEA AND CHARACTERISTICS OF A REINFORCING FEEDBACK OF DISRUPTIONS IN SUPPLY CHAINS

The concept of feedback in supply chains draws on systems thinking and provides several implications for breaking out of reactive mindset that comes inevitably from a simple linear thinking. First of all, the concept of feedback means any reciprocal flow of influence. In other words it posits that each influence is both *cause* and *effect* and nothing is ever influenced in just one direction. Instead of direct cause and effect relationship one should see relationships in a particular indirect sequence. Consequently, it is important to see reality systematically as circles of influence rather than straight line [1]. Every circle tells a story showing how the structure creates a particular pattern of behavior or, in case of a complex structure such as supply chains, several patterns of behavior, and how that pattern might be influenced.

The feedbacks may be graphically depicted as a feedback circle diagram which shows system wide interrelationships [1]. It is important in resolving supply chains as dynamic complex system, in which strategic choices on the forces that shape change and organizational disruptions are made. In order to describe *cause - effect* nature of disruptions in supply chains, a language of interrelationships, made up of circles is needed. Therefore, a feedback circle diagram may be very instrumental when the transmission of disruptions is considered.

In practice, the risk of adverse effects caused by the certain factors, are often transferred to the other links in the supply chain [2]. It means the negative effects of risk are extended beyond the boundaries of individual firms and thus, indirectly transferred to the other companies. The propagation of the negative effects of risk from one company to the other firms as a result of indirect impact of certain risk factors may be called as the transmission of disruptions. For instance, improper unloading of the product by a customer may cause a damage to the manufacturer's transportation infrastructure, which may result in accumulation of stock at a supplier caused by an unavailability of transportation means due to the damage. The sequence of different disruptions observed in succeeding links in resilient supply chains may affect on the improvement and greater caution of unloading process at the customer in future.

To summarize, the transmission of disruptions means that the negative effects of risk are extended to a larger number of participants in a supply chain. The primary source of these disruptions are external and internal risk factors. In the opinion of Tchankova sources of risk are the factors in the organizational environment that can bring some negative outcomes. In other words, the factors are subjects, objects, events, places, processes etc. which may be the causes of risk [3].

Depending on the direction of propagation, the transmission of supply chain disruptions can take the form of forward, backward and bidirectional (two-way) transmissions [4] [5]. The forward propagation denotes that the disruptions caused by the exogenous or endogenous risk factors in the initial link are then transferred to the other echelons in a supply chain. The backward propagation is originated when the disruptions in the ultimate link of a supply chain are transferred to the initial echelons. The bidirectional transmission, in turn, is caused by the disruptions in the echelon located in the middle of a supply chain structure, which are then spread to the upstream and downstream links of a supply chain.

The disruptions may be amplified while propagation bringing analogy to reinforcing feedback process, which is the engine of growth or accelerating decline. A pattern of decline exists where small drops amplify themselves into larger and larger drops, such as the decline in bank assets when there is a financial panic [1]. The example of accelerating decline is also the amplification of disruptions during the transmission from one company to the others which may be therefore illustrated with a reinforcing feedback of disruptions.

It is important to highlight that each subsequent link in supply chain structure is exposed to the stronger effect of a particular disruption, even though the disruptions may differ while transmission from one link to the other. The effects of local and non-local risk factors should be taken into account by managers. However, sometimes the disruptions are totally unknown, which can obscure any clear cause-and-effect relationship [6]. Therefore, managers should be aware that the occurrence of a reinforcing feedback of disruptions is strongly connected to growing supply chain complexity manifested in increasing number of internal and external relationships. Hereby, the complexity is driven by supply chain interdependence.

INTERDEPENDENCE AS A DRIVER OF SUPPLY CHAIN COMPLEXITY

Supply chain interdependence is shaped by relationships with external partners. It drives complexity of supply chains as in the result of strong interactions among elements, current events can heavily influence the probabilities of many kinds of later events [7]. Therefore, interdependence is primarily determined by the span of supply chain structure. The span may be referred to the network perspective of supply chains. It is established by autonomous business entities involved, through upstream and downstream links, in

different business processes and activities concerning physical, information and finance flow [8]. Consistently, Mentzer *et al.* argue that supply chain may be perceived as “a set of three or more companies directly linked by one or more of the upstream and downstream flows of products, services, finances and information from a source to a customer [9].

For the purpose of the study, it seems to be necessary to distinguish between supply chain structures involving supporting members which perform the logistics activities and supporting members which execute the non-logistics activities. Therefore, it is assumed that the basic supply chain is constituted by the primary members, the extended supply chain comprises basic structure expanded by the supporting members performing the logistics activities, whilst ultimate supply chain encompasses an extended structure expanded by the supporting members performing the non-logistics activities [10] [11] [12] [13] [14] [15].

Growing interdependencies in supply chains enable the links to transmit information more effectively and lead to opinion making among partners. Therefore it strengthens the organizational ability and capability to learn [16] and has a beneficial impact on overall organizational performance. Yet, the span of supply chain structure may also be interrelated with a reinforcing feedback of disruptions and therefore requires more profound empirical study.

METHODOLOGY

In order to investigate the role supply chain interdependence in a reinforcing feedback of disruptions, an exploratory study using a quantitative survey as a method of data collection was conducted. Consequently, the framework of an interview questionnaire corresponds to the goal of the paper.

The main research instrument used for this study was a questionnaire consisting of several sections examining supply chain interdependence and the phenomenon of a reinforcing feedback of disruptions. The set of data collected within the first release of the survey was gathered in European supply chains.

For the purpose of the research presented in this paper, a group of relevant variables has been selected. Firstly, a number of 3 items was employed in order to examine supply chain interdependence. They manifested basic, extended and ultimate supply chain structure. In addition, a large portion of 43 variables measured a reinforcing feedback of disruptions This group was additionally characterized by risk sources, direction of the transmission of disruptions and type of the flow in supply chains.

In order to empirically measure if a reinforcing feedback of disruptions, the leaders or major links, which have a relatively strong position and possess ongoing knowledge on risk management issues in their supply chains, have been asked to rate the strength of particular disruption in the subsequent companies establishing supply chain structure (i.e. the companies, which were directly and indirectly affected by a disruption). Additionally, the disruptions have been classified into three groups, including disruptions in material, information and finance flow, and separated regarding the type of forward and backward transmission. The asked question sounded: “Rate the strength of following disruptions, which affect your company, your suppliers and your customers”. Moreover, the respondents were asked to get the strength of disruptions averaged over all suppliers and customers. For instance, in the forward transmission, the strength of particular disruption (e.g. breakdown of logistic and manufacturing infrastructure at suppliers), affecting the examined company, its suppliers and customers, was rated by the respondent. The obtained data enabled to assess the difference between the strength of disruptions in the final link, which was indirectly affected, and the link, directly affected by a particular disruption. If the calculated difference is positive it denotes that a reinforcing feedback of disruptions exists, while its negative value suggests a mitigation of the strength of disruptions in the transmission.

The rest of the survey contained demographic items concerning operating industries exploring a sectoral representation of the units, number of employees, organizational structure, number of product lines manufactured and delivered by investigated supply chains, etc.

The sample was compiled from the surveys of manufacturing and trading companies operating in supply chains, and consisted of 134 organizations. Those firms were leaders or major links in their supply chains consisting of at least three subsequent links.

The majority of the surveyed firms (55 percent) are manufacturers, remainder of the research sample includes trade companies. The prevailing share of the companies operate in wholesale and retail grocery sector (27 percent), fabricated metal products, industrial and commercial machinery sector and manufacturing of motor vehicles (a total of 25 percent), followed by the companies from a mining industry (16 percent), trading companies (selling cross-industry products, mainly household goods – 15 percent, clothes – 5 percent, chemicals – 4 percent, electronic equipment – 3%).

THE RELATIONSHIP BETWEEN SUPPLY CHAIN INTERDEPENDENCE AND REINFORCING FEEDBACK OF DISRUPTIONS

In order to address the goal of the paper, the companies were grouped regarding supply chain interdependence. In the result of clustering, the first class consists of 19 basic supply chains, which represent almost 14% of the whole sample. The second group accounts for 56 extended supply chains, which constitutes almost 41% of the sample, whereas the third cluster includes 61 ultimate supply chains with the share of 45% of the whole sample.

The groups of supply chains obtained through cluster analysis were then characterized in terms of reinforcing feedback of disruptions. The set of mean scores of variables, rounded to .5 to ease the interpretation of findings, was additionally split in each of individual clusters with respect to the type of physical, information and finance flow in supply chains. The findings were captured for the forward, backward and two-way transmission of disruptions.

In general, the study suggests that reinforcing feedback of disruptions occurs across all of three clusters, however its strength differs regarding supply chain interdependence.

The amplification in the forward and backward transmission may be clearly observed in the physical flow of products in basic and extended supply chain structure. For instance, the disruptions caused by the risk located in the company at the layer 'n-1' in supply chains are propagated forwardly to firms at the layers 'n' and 'n+1' in the structure of a supply chain. However, as supply chain structure expands, becoming more complex, the tendency of declining of the strength of disruptions may be revealed.

The results suggest that the disruptions are magnified in a basic supply chain structure, and decrease in ultimate supply chains. A very similar tendency may be noticed while analyzing the variation of the strength of disruptions in the backward propagation in the physical flow of products.

On the other hand, the companies still report a reinforcing feedback of disruptions in the forward and backward transmission in the information flow, however the strength of disruptions decreases while propagation, regardless of supply chain structure. One may conclude that the increase of the complexity of supply chain structure does not result in amplifying nor mitigating the negative risk consequences. It seems that the relationship between a reinforcing feedback of disruptions in the forward and backward propagation in the information flow and supply chain interdependence has a neutral character. Furthermore, the conducted research suggests that a reinforcing feedback of disruptions in the finance flow is not dependent upon supply chain interdependence.

Consequently, one may conclude that the strength of disruptions being transferred in the finance flow is diminished and simultaneously it is not determined by supply chain interdependence. The findings may suggest that although the problems of cash settlements are not transferred to the financial sphere in supply chains, but they may cause increased disruptions in the material flow. This probably represents one of the major reasons of stronger impact of a reinforcing feedback of disruptions in the physical flow of products. Furthermore, it should be noted that the disruptions in

the finance flow are not only propagated to the companies participating in the flow of products. They can also come from the traders and providers of non-logistical services (e.g. banks, investment funds, insurance companies, etc.). The propagation of negative effects caused by the risks located in those links may be one of the factors contributing to a reinforcing feedback of disruptions in the forward and backward transmission in the material flow of products in supply chains.

Interesting conclusions may be drawn when analyzing a reinforcing feedback of disruptions in the bidirectional transmission. There is a distinct tendency of stronger risk effects in two way propagation affecting the links located downstream supply chains, closer to the market and ultimate customers. The stronger impact is observable in all three kinds of flows in examined supply chains. The companies located more upstream in supply chains report relatively lower impact of disruptions transmitted from the subsequent echelons. It is worth noting that the more interdependent supply chain structure, a feedback of disruptions tends to decrease. The companies preceding the first link generating bidirectional transmission are practically not exposed to risk effects. Consequently, one may conclude that this group of companies is not vulnerable to the disruptions originating from the subsequent links.

Generally, the obtained findings suggest that in specific situations, supply chain structure determines a reinforcing feedback of disruptions in the forward and backward transmission. The increasing strength of a feedback is very well observed in the physical flow of products. On the other hand, a reinforcing feedback of disruptions may be observed in the forward and backward transmission in the information and finance flow, however, it seems to be independent from supply chain structure. In the light of the findings, interdependent structure tends to inhibit a reinforcing feedback of disruptions. This seems to be consistent with the opinion of Jüttner *et al.* which advocates that supply chains interdependence can either absorb or amplify the impact of events arising from environmental or organizational risk sources. The Authors notice that similarly, as the construction of a building is decisive in terms of disruptive impact of an earthquake, the interdependency influences the supply chain effect of events arising for example from environmental risk sources [17].

FURTHER RESEARCH

The obtained findings revealed that an interesting issue which requires more in-depth study is to define ways of identification and measurement of a reinforcing feedback in the transmission. This may enable to make cross-sectoral and international comparisons of this phenomenon. Another problem is to reveal managerial methods and instruments to mitigate a reinforcing feedback of disruptions. This study would define an appropriate attitude of supply chains towards that phenomenon and indicate exemplary strategies preventing from its negative effects.

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