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Propagation of amplified disruptions in supply chains.
Conceptual perspective and practical implications

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ABSTRACT

The paper seeks to develop a conceptual framework for analyzing the propagated and amplified disruptions in the supply chains and provides findings of a cross-sector empirical study conducted among the practitioners dealing with the risk effects in their organizations.

Keywords: risk, disruption, supply chain

INTRODUCTION

Nowadays, the supply chains are more susceptible to the propagation of amplified disruptions. Its intensity and extent is, in particular, a result of permanently raising complexity of interorganizational networks of the supply chains. The key issue of the supply chain concept is establishing relationships which enables to generate a relational rent (Dyer and Singh, 1998). It is an additional profit for the whole supply chain and its members which often determines achieving and sustaining the competitive position of the organizations. However, the relationships in the supply chain may also bring the negative consequences for its members, being a source of propagation of amplified disruptions. The paper is structured into several sections.

Following the introduction, the idea of the propagation of amplified disruptions in the supply chain is explained. Based on those considerations, a conceptual framework for analyzing the propagated and amplified disruptions in the supply chains is developed. It is then used for an empirical study conducted among practitioners dealing with the negative risk effects in their organizations. The empirical findings derived from the analysis have been presented and discussed. Finally, the conclusions of the research are drawn and the implications for further empirical studies are indicated.

THE PROPAGATION OF DISRUPTIONS IN THE SUPPLY CHAINS

The supply chain, which in the last few years has been a subject of intense research both in the theoretical and practical frameworks, is currently one of the most dynamically developing concepts (Kisperska-Moron and Swierczek, 2009). For the purpose of this paper supply chain is defined 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” (Mentzer, 2001).

The supply chains are often exposed to the negative effects of risk often referred to as disruptions. They may directly or indirectly affect the organizations. The direct impact of disruptions can be triggered by the exogenous or endogenous risk factors. The exogenous risk factors are external to the supply chain and located outside its boundaries. They fall into a wider macro environment level or sector whereas endogenous risk factors are embedded inside the supply chain – its participants or relationship between them (Rao and Goldsby, 2009; Peck, 2004; Cavinato, 2004).

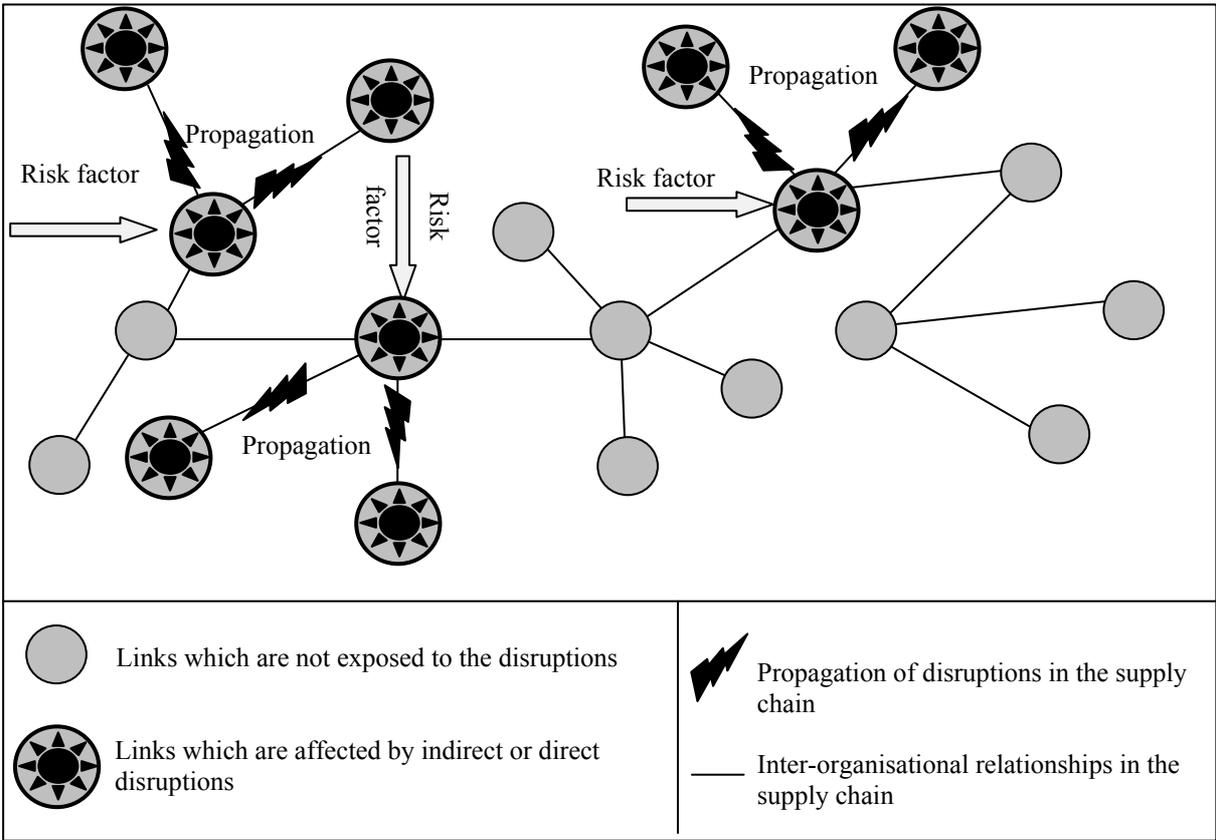


Fig.1. The propagation of disruptions in different parts of the supply chain structure

Źródło: Adapted from: S.K. Cheng, B.H. Kam: *A conceptual Framework for analyzing risk in supply networks*. Journal of Enterprise Information Management. Vol.22, No.4, 2008, s. 345-360.

In practice, the risk of the adverse effects caused by the certain factors, are often transferred to the other links in the supply chain. It means the negative effects of risk are extended beyond the boundaries of individual firms and thus, indirectly transferred to the other companies. The

transmission 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 a propagation of disruptions.

The range of the propagation of disruptions may extend beyond the framework of bilateral ties. The negative risk effects may, in fact, spread to a larger number of participants in the supply chain. This range can be varied, but generally falls within the two types of disruptions placed on the extreme positions of the continuum (Svensson , 2000):

- Limited range of disruptions, usually bilateral;
- Widespread disruptions, generally holistic.

In the limited range of disruptions, the negative effects of risks are propagated to the small number of links in the supply chain. For the purpose of this paper, this range consists of only two companies, which determines the transmission of disruptions from one company to the other. It is not important if a disruption in the first link is caused by the endogenous or exogenous risk factors. At the other extreme continuum outlining the propagation of the negative effects are widespread disruptions. The transmission of these disruptions is covered by all the actors in the supply chain.

Generally, the effects of risks are positioned between the two poles of limited range and widespread disruptions. Then a certain number of actors participating in the supply chain will be exposed to the negative effects of risk.

In practice, there may be several risk factors occurring simultaneously in different parts of the supply chain. As depicted in Figure 1, there are three independent risk factors, each causing negative effects in different parts and links of the chain.

THE FRAMEWORK FOR ANALYZING THE PROPAGATION OF AMPLIFIED DISRUPTIONS IN THE SUPPLY CHAIN

The disruptions may be amplified during the propagation in the supply chain. It means that each successive link in the supply chain can be exposed to the stronger effects of risks. The phenomenon of the propagation of amplified disruptions is illustrated in Figure 2.

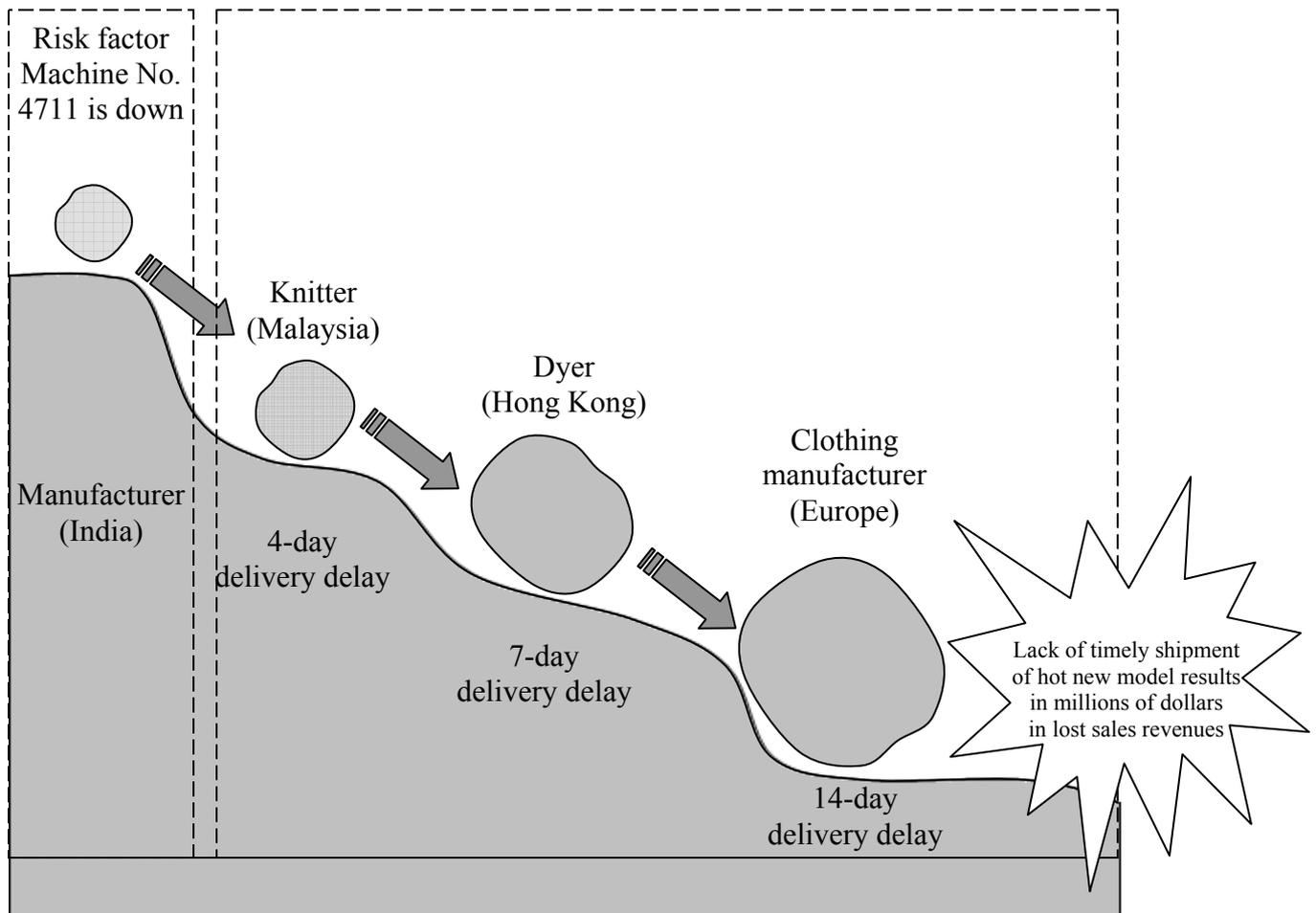


Fig.2. The amplification of disruptions in the supply chain

Adapted from: Radjou N., Orlov L.M., Nakashima T.: *Adapting To Supply Network Change*. The TechStrategy TM Report, March 2002. p. 3

As depicted in Figure 2, a malfunction of the machine at the manufacturer in India caused a delivery delay which was then amplified in a propagation process to the subsequent links in the supply chain. The lack of punctual shipments results in the loss of sale revenues worth millions of dollars. However, the effects of risk should not be considered only in terms of the financial perspective. In the opinion of Cousins et al., there are many other important negative

effects of risk, apart from the financial losses, namely decline in the product quality, destruction of property and machinery, loss of a positive image in the market, etc. (Cousins *et al.* 2004; Standards Australia, 1995).

The propagation of amplified disruptions means that the negative effects of risk are intensified and expanded on a larger number of participants in the supply chain. The primary source of these disruptions are exogenous and endogenous risk factors. Therefore, it may be assumed that the propagation of disruptions requires at least two companies of the supply chain to be involved in a process. One company is affected by a direct impact of these risk factors, and the other is affected by an indirect influence.

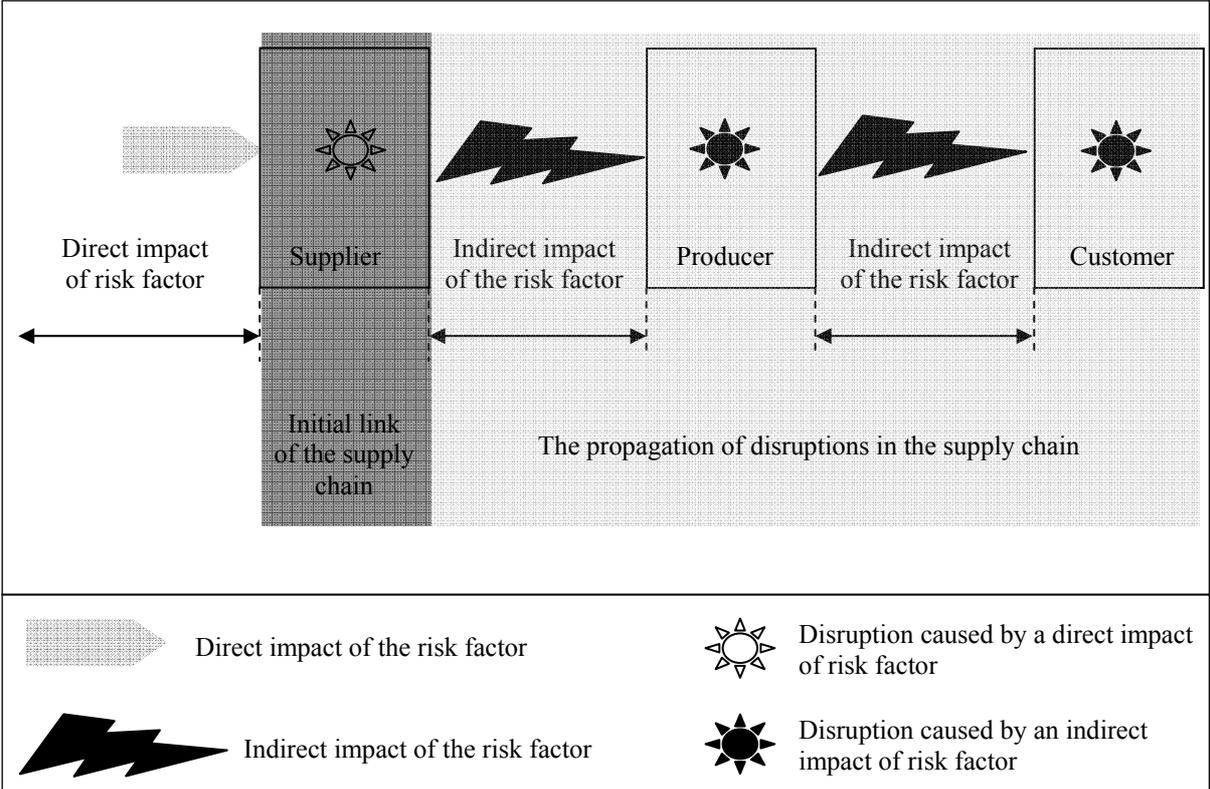


Fig.3. The simplified framework for analyzing the propagation of amplified disruptions in the supply chain

The simplified framework for analyzing the propagated and amplified disruptions in the supply chains is depicted in Figure 3.

For instance, the exogenous or endogenous factors affect directly on the supplier, causing a certain disruption, which is then transmitted inside the structure of the supply chain to the

other participants. In this case, the supplier is an initial link, while the actors at other levels of material flow in the supply chain - producer and customer are exposed to the indirect impact of risk factors. Therefore, it ought to be an indirect impact of the risk factors in the transmission of disruptions.

An analysis of the propagated and amplified disruptions becomes more complicated in terms of the direction of the transmission. This transmission may take the form of forward, backward or two-way propagation – Figure 4.

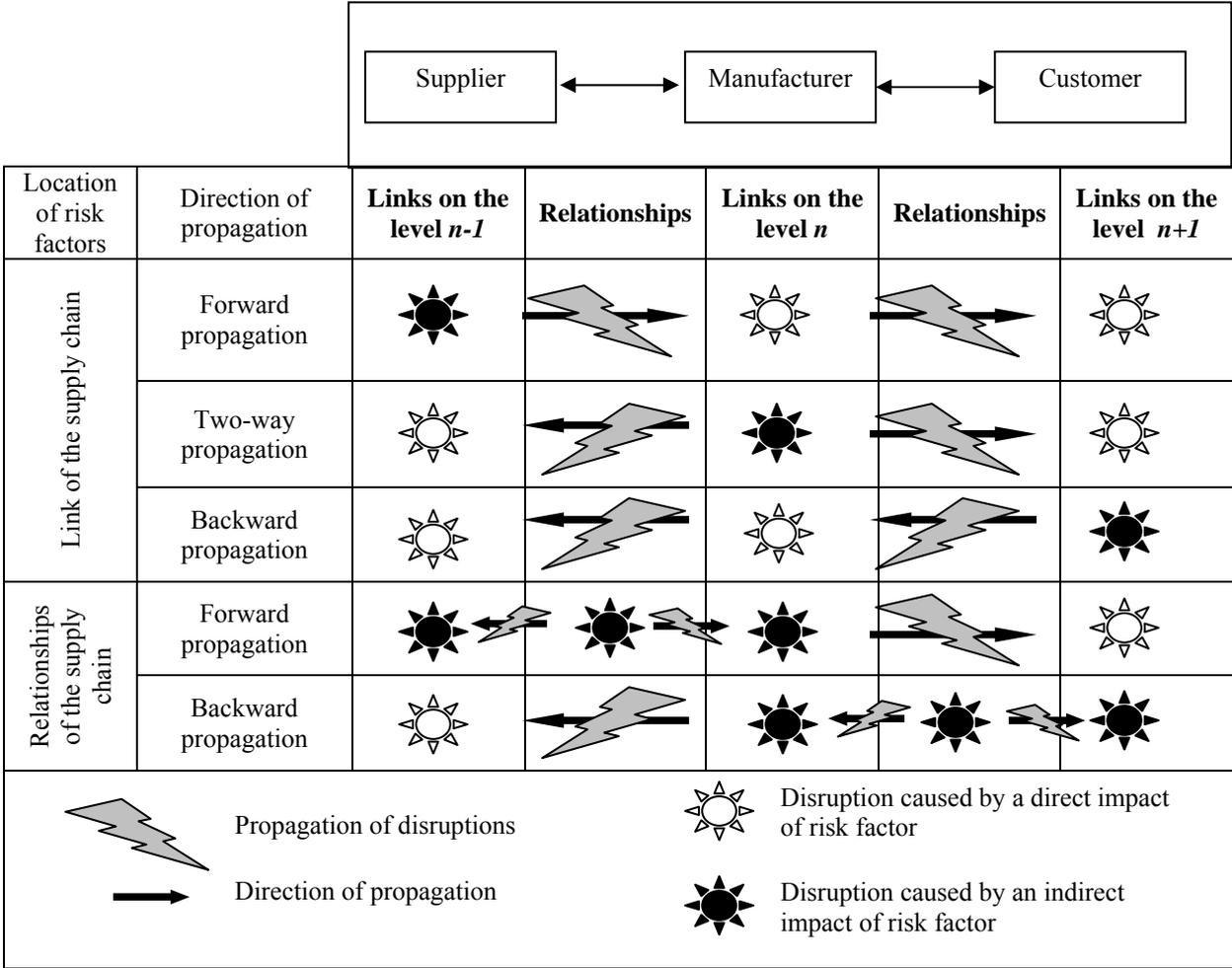


Fig.4. The extended framework for analyzing the propagation of amplified disruptions in the supply chain

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 the supply chain.

The backward propagation occurs when the disruptions in the ultimate link of the supply chain are transferred to the initial echelons. The two-way propagation means that the disruption in a company located somewhere in the middle of the supply chain is then transferred to the other links. Finally, considering the direction, the transmission of disruptions arising from inter-organizational relationships, can take the form of both forward and backward propagation.

It should be noted that the framework for analyzing the propagation of amplified disruptions is illustrative. Depending on the structure of the supply chain, the propagation of disruptions may take more complex forms, which often makes it difficult to unambiguously analyze this phenomenon.

SAMPLE AND DATA COLLECTION

In order to verify a conceptual framework for analyzing propagated and amplified disruptions in the supply chains, a preliminary research has been conducted. It provides findings of a cross-sector empirical study conducted among practitioners dealing with the risk effects in their organizations

The main research instrument used for this study was a questionnaire consisting of several sections examining the phenomenon of the propagation of disruptions. There is no single meta-theory for guiding the development of the survey. Instead, many aspects of general managerial practices were a subject of investigation. Data collected within the first release of the survey were gathered in 2011 in Polish companies.

For the purpose of the research presented in this paper, a number of 43 variables have been selected. The items were gathered using 7-point Likert scale reflecting respondents' attitude towards the strength of transmitted disruptions. The sample was compiled from the surveys of manufacturing and trading companies and originally consisted of 216 firms. As a result of initial data analysis, screening and elimination of observations with missing values, a

group of 144 companies remained as the subject of further analysis. Those firms were leaders or major links in their supply chains consisting of at least three subsequent links.

The majority of the surveyed firms (65 percent) are trade companies, remainder of the research sample includes manufacturers. The prevailing share of the companies operate in wholesale and retail grocery sector (13 percent), fabricated metal products, industrial and commercial machinery sector and manufacturing of motor vehicles (a total of 12.5 percent), followed by the companies from a mining industry (8 percent), trading companies (selling cross-industry products, mainly household goods – 6 percent, clothes – 5 percent, chemicals – 4 percent, electronic equipment – 3%).

The prevailing share of 68 percent of the sample employed up to 9 people, followed by 17 percent of the companies employing from 10 to 49 persons. Much smaller share of 9 and 7 percent of the sample belonged to the companies employing from 50 to 249 and above 250 people respectively. The sample consists mainly of the small companies.

THE ANALYSIS OF THE PROPAGATION OF AMPLIFIED DISRUPTIONS IN THE SUPPLY CHAIN. PRELIMINARY RESULTS

The aim of the study is to provide the findings of a cross-sector empirical study conducted among practitioners dealing with the propagation of amplified disruptions in their supply chains. Table 1 presents the results of the study concerning the forward, backward and two-way propagation of amplified disruptions in material, information and finance flow in the supply chains.

The preliminary study suggests that the propagation of amplified disruptions exists in a physical flow of products in the supply chains. The risk factors located in the subsequent links of the supply chains generate the disruptions which are then transmitted with a greater strength to the other companies. The increase in the strength of the propagated disruptions clearly observed in the forward and backward transmission in the material flow of the

examined supply chains may indicate the phenomenon of the amplification of disruptions. For instance, the disruptions caused by the risk located at the ‘n-1’ links are propagated forwardly and amplified in the companies at the levels ‘n’ and ‘n+1’ in the structure of the supply chains.

An analysis of empirical material suggests that the strength of disruptions caused by the risks located in the links during the forward and backward propagation in the information flow decreases. This may mean that the transmitted disruptions are not amplified in the information flow, but simultaneously may spread to the other links involved in the material and finance flow in the supply chains.

Table 1. An empirical analysis of the propagation of amplified disruptions in the supply chain (median scores)

Location of risk factors	Direction of propagation	Type of flow	Links on the level n-1	Links on the level n	Links on the level n+1
Links of the supply chain	Forward propagation	Material flow	4,00	4,00	4,50
		Information flow	4,00	3,50	2,50
		Finance flow	4,00	2,00	1,00
	Two-way propagation	Material flow	3,00	2,00	3,50
		Information flow	2,00	5,00	3,00
		Finance flow	2,00	4,50	2,00
	Backward propagation	Material flow	3,50	3,00	3,00
		Information flow	1,50	3,00	3,50
		Finance flow	1,50	3,00	3,50
Relationships of the supply chain	Forward propagation	Material flow	3,50	4,50	2,50
		Information flow	3,00	3,00	2,00
		Finance flow	3,00	4,00	1,00
	Backward propagation	Material flow	1,00	4,00	3,00
		Information flow	1,00	3,00	3,00
		Finance flow	1,00	4,00	3,00

The results also revealed a clearly delineated tendency in the decrease of disruptions in the forward and backward transmission in the finance flow. This may suggest that although the problems of cash settlements are not transferred to the financial sphere in the supply chain, but they may cause increased disruptions in the material flow. This represents probably one of the major reasons of the increase in the strength of disruptions in the physical flow of products. In addition, 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 (et. 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 the increase of the strength of disruptions propagated forwardly and backwardly in a material flow of products in the supply chains.

The interesting conclusions may be drawn regarding the analysis of two-way propagation of disruptions in the product, information and finance flows. In general, the companies positioned close to the market and ultimate customers are exposed to the stronger disruptions transmitted from the preceding links. The companies located more upstream in the supply chains report relatively small impact of disruptions transmitted from the subsequent echelons.

The obtained results suggest that the phenomenon of the propagation of amplified disruptions caused by the risks located in the relationships is not observed. It is interesting to note that the companies directly affected by the negative effects of the risks arising from the relationships report a strong impact of disruptions. The strength of the negative effects of risk decreases during the propagation to the subsequent links of the supply chain.

Summing up, the most noticeable tendency of the propagation of amplified disruptions may be observed in a physical flow of products. It is a very important result as the material flow plays a vital role for effective supply chains. Based on the results of the preliminary study, the proposed framework for analyzing the propagation of amplified disruptions should

be positively verified as it serves a crucial role for identification of the phenomenon. Therefore, it is worth noting that the propagation of amplified disruptions seems to be a vital ingredient of the contemporary supply chains. However, its extent and strength differ considering the type and direction of flow in the supply chain which should be definitely considered by practitioners and managers while making a decision process.

The conducted study also indicates that the propagation of amplified disruptions in the supply chains requires further in-depth and extensive analysis. It is a very interesting issue but still unexplored and unexplained.

FUTURE DIRECTIONS AND FURTHER RESEARCH

Although the presented study is in the initial stages, it provides preliminary insights into the propagation of amplified disruptions in the supply chains, and also highlights potential areas of future research. It would be interesting to conduct a study on the major determinants of the propagation of amplified disruptions in the supply chains. One of the most important basis for a transmission of disruptions in the supply chains seems to be a collaboration of companies. It may be assumed that the more intense relationships among the supply chains partners, the larger chance for the propagation of amplified disruptions. Therefore, it would be interesting to investigate how the collaboration between the companies contributes to the transmission of amplified disruptions in the supply chain.

This analysis might also reveal the managerial methods and instruments mitigating the strength of the propagated disruptions. The study should define an appropriate attitude of companies towards phenomenon of the transmission of amplified disruptions and indicate exemplary strategies preventing from the negative consequences of disruptions transmitted along the supply chain. The study's potential use to practitioners could also rest in the

development of a model in specific sectors to determine the way it behaves in terms of the propagation of amplified disruptions.

Finally, an interesting issue needing of investigation is to examine the environmental circumstances which may contribute to the phenomenon of the propagation of amplified disruptions in the supply chains.

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