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Vulnerability of Sustainable Supply Chains: Demand-Side Approach*

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Abstract:

Purpose: *Changing economic conditions, including increasingly complex relationships between actors in the supply chain, are making the supply chain more sensitive and are lacking in transparency. The main research problem was whether or not demand uncertainties affect the vulnerability of sustainable supply chains (SSC).*
Design/Methodology/Approach: *The following research methods were selected: literature analysis, and empirical research - questionnaire. The analysis and interpretation of the data obtained from the qualitative research were developed using quantitative methods - descriptive, as well as statistical, where the analysis of variance-ANOVA was used.*
Findings: *Several factors influencing the sensitivity of SSC has been identified. One of the most frequent factors was the uncertainty of demand. Global trends in the implementation of sustainable development principles in various economic spheres, as well as customer requirements to offer organic products, are forcing adjustment decisions in the supply chain. Demand side and consumer research allows to design supply side research. The results should give a chance to confront and explore the relationships between customer expectations and what in terms of vulnerability is done by the links in the supply chain. This approach can identify common elements and differences in understanding not only sustainable chain strategies but will also allow the creation of a catalogue or model to create defensive mechanisms and immunization of sustainable supply chains.*
Practical Implications: *Implications for business practice may relate to the identification of directions, areas and processes for the implementation of sustainable development principles in the supply chain strategy, in order to increase their efficiency, competitive position and the level of innovation as well as to identify customer expectations regarding the purchase of organic products and to identify elements that may affect the vulnerability of such a chain.*
Originality/value: *The novelty and originality of the considerations is to examine the demand side in the context of the sensitivity of sustainable supply chains. A novelty is shown how dedicated groups of buyers indicate assessment of the importance of the different aspects: social, ecological, financial, and economic aspects of SSC. This can be the basis for original supply side research.*

Keywords: *Estimation, time-series models, foreign exchange, portfolio choice.*
JEL classification: *Q11, Q13, C44.*
Paper Type: *Research study.*

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1. Introduction

Today's supply chains must not only be efficient and integrated to be competitive, (Kaleel Ahmed *et al.*, 2018) but they must also meet the challenges of global economies and the changing expectations and preferences of customers. The pressure to reduce costs, increase efficiency (including shortening the time and ensuring a high level of product quality and chain functioning), building resilience or to meet the changing needs of consumers is accompanied by the need to protect, or at least not harm, the environment (Xu *et al.*, 2018).

The above challenges are accompanied by phenomena which, with development and including of appropriate strategies and tools, should make supply chains more efficient, greener, and more economical. One of them is vulnerability of the supply chain. It can be defined as the exposure to serious disruptions resulting from different risk categories within the supply chain as well as from external threats to the supply chain. Many literature resources on vulnerability in supply chains have been published over the last 15 years, so it seems important to address this issue (Elleuchet *et al.*, 2016) in the context of sustainability, organic product and one of uncertainty, which have an influence of the supply chain, namely demand uncertainty. The future trends in supply chain management will be oriented towards greater transparency, sensitivity, and resilience of supply chains (Kirchoff *et al.*, 2016). The aim of this paper is to show if and how demand uncertainties can have an effect of the vulnerability in SSC.

The theoretical part, developed from the supply side perspective in the context of the SSC strategy, was confronted with the results of the demand side research (i.e., the focus was on organic buyers). This approach showed the impact of consumer demand on chain vulnerability. The focus was on identifying and developing recommendations on how to improve SSC resilience and how to mitigate risks, with a particular focus on aspects related to demand uncertainties. During the research process, empirical studies were carried out among consumers to discover if identified purchasing preferences could influence the vulnerability of the SSC. Reference was made to the willingness or lack of willingness to incur higher costs because of reflecting a higher price for the consumer, which may affect the vulnerability of the SSC. A higher price for a product, including, but not limited to, elements related to the implementation of sustainability in the supply chain, may be a factor directly affecting demand uncertainty, which may determine the vulnerability of a sustainable chain.

The considerations undertaken are accompanied by the following research methods. In the theoretical part, (1) a critical analysis of literature was carried out to construct a theoretical basis, of research in SSC and its vulnerability of functioning were examined. Then, research methods were defined. For empirical research, (2) was selected a qualitative method. Dedicated questionnaire was conducted on a selected

group of respondents. The analysis and interpretation of the data were developed using quantitative methods (3) - descriptive and statistical (analysis of variance-ANOVA).

The rationale for undertaking research is identified by the authors lack of empirical analysis and theoretical basis in the literature on issues related to the vulnerability of a SSC. Much attention is paid to uncertainty, identified as part of the demand-side issues. At the same time, the critical factors that influence the vulnerability of SSC can be identified. Their classification and systematics may refer, in classical terms, to 3BL covering the areas of economics, environment and society, as well as in process terms, or including stakeholders. In this context one of the factors is the uncertainty in demand. This is a direct factor increasing SSC sensitivity, vulnerability, and resilience. Knowledge of customers' preferences and their purchasing decisions, particularly for organic products, may contribute to reducing the level of demand uncertainty. This is related to a greater propensity to incur higher costs of products (which consists e.g., higher operating costs of a Sustainable Supply Chain). The level of uncertainty depends also on the intensity and regularity of the purchases, the type of products, and the size of the product range. In consequence, a reduced risk of uncertainties in demand increases the resilience of the chain. Objectives of the paper:

(1) Identification of the critical factors influencing on the vulnerability of sustainable supply chains (SSC) included identification of sources of uncertainty for sustainable supply chains, with reference to the uncertainty of demand.
(2) Diversifying consumer groups declaring the purchase of organic products in the context of SSC vulnerability.
(3) Analysis of the relationship between SSC vulnerability and knowledge of consumer preferences (in the context of selected factors).

The remainder of the considerations is organized as follows. The literature background section reviews the relevant literature. The data collection and findings section show research methodology and analyses, included the data collection method, and empirical results. Discussion and limitations provide a discussion of our findings, and the conclusion section includes some remarks and directions of future research.

2. Literature Review

There are many terms in the literature that describe the supply chain and its strategies and determine the decisions to be taken therein. In the context of the paper the following determinants were considered as important: the aspect of sustainability and greening the chain, the vulnerability and resilience of the chain, and the criteria referred to as chain uncertainties - or rather the factors that influence them. The combination of these elements is a scientific challenge, providing the opportunity to better match and dedicate mechanisms to reduce uncertainty, and decreases of

vulnerability while making an SSC more resilient. As environmental pollution, wastefulness, and ecological imbalances are the focus of global attention, SSC management has become an important direction for their development and research area (Hu *et al.*, 2019; Montabon *et al.*, 2016; Zhang and Yang, 2020). Despite a significant increase in quantitative research (i.e., scientific articles) on SSC, their relationship to the concept of vulnerability remains insufficiently explored. Waters (2007) discussed the management and design of vulnerable supply chains in logistics aspects and trends in their development. Chappell and Peck (2009) presented an example of an industry approach to vulnerability analysis by writing about risk management in military supply chains. The Supply Chain Vulnerability Executive Report (2002) highlighted the inherent nature of business and supply chain vulnerabilities to emerging disruptions. However, vulnerability is affected by uncertainties, especially those related to demand. The vulnerability of modern supply chains is quite simply becoming a cause of disruption and negative effects for the participating companies (Hendricks and Singhal, 2005; Wagner and Bode, 2008; Wagner and Neshat, 2010).

Uncertainty is a phenomenon related to the probabilistic nature of decision making that affects the achievement of the assumed goals of the supply chain. The uncertainties and risks that arise are most often related to the failure to meet expectations. Uncertainty, as a cognitive category, manifests itself in a lack of information necessary to make decisions, inability to predict the effects of decisions, and, finally, inability to estimate the effects of events occurring in the environment. The type of uncertainty that can be measured is called risk. Peck *et al.* (2003) defined risk in the supply chain as a change/disruption in the distribution of possible supply chain results, their probability, and the occurrence of subjective values. These changes, or disturbances, affect the flow of goods and information throughout the unit. Zsidisin (2003) defined supply risk as the probability that a supply incident, caused by a failure in the supply market or in individual suppliers, will occur, with the result that a company loses the ability to meet customer demand or creates a threat to their life and safety.

In the context of supply chain risk can be described in relation to two categories of: external and internal (Deloach, 2000). External risk is primarily the risk related to the operation of force majeure: natural disasters, terrorist acts, changes in the operating conditions resulting from political, legal, and other instability, etc. This type of risk does not result from decisions taken in supply chain management. The internal risk associated with the functioning of the supply chain includes: the risk associated with lean practices (e.g., outsourcing, single souring, just-in-time), the risk associated with relations between partners in the supply chain (e.g., opportunism), the risk associated with the functioning of the supply chain (e.g., lack of a single owner, Forrester effect, chaos, inertia), and the risk associated with the flow of information in the supply chain. The sources of the risk identified are in supply chain or individual company decisions, but the effects of these decisions

affect companies throughout the chain (Wagner and Bode, 2008). Undoubtedly, the risk is also affected by the uncertainty of demand and the reactions of the customers. The transparency of the chains is also an important element influencing their vulnerability. It provides insight into conditions (demand and supply, production and supply schedules, inventory levels maintained in the supply chain links constituting the supply network, as well as in the supply chain links constituting the distribution network) using explicit communication channels and agreements on a uniform set of measures.

Lack of transparency in the supply chain forces managers to make decisions based on forecasts, thus maintaining inventories (i.e., buffers) that do not correspond to actual demand. In such a supply chain, there are so-called over-concentration of operations, resulting from striving to take advantage of economies of scale, quantitative discounts and reduction of transaction costs, with a tendency to over-focus operations at a particular link in the chain. Excessive concentration reduces supply chain flexibility to respond to changes in the environment and leads to greater susceptibility to sudden disturbances, which is sometimes called supply chain fragility (Hendricks and Singhal, 2012), affecting his vulnerability.

Under such conditions, it is necessary to create resilient supply chains (robust supply chains) adapt their strategies and operations to changes in the environment to reduce the risk of loss of performance. They are resistant to various types of anomalies, perturbations, effects of failures or malfunctions resulting from the breach of existing operating conditions, or disruption of continuity of material and information flows. From a managerial perspective, this means aiming to avoid disruptions or reduce their severity if they occur (Boin *et al.*, 2010). Economic, social, and natural risks are an integral part of the supply chain, involving they carry a risk of unpredictability. Good planning, as well as awareness of possible crisis situations, reduces uncertainty and mitigates negative consequences resulting from potential risks because disturbances in the functioning of chains reduce its effectiveness. To reduce risks and disruptions in the chain and to create increasingly resilient chains, their design must be tailored to include the measures needed to provide an effective and efficient response to unforeseen events (Soni *et al.*, 2014). At the same time, it must be sufficiently resilient to return to its original state or better than it was before the disruption (Ponomarov and Holcomb, 2009; Ivanov and Sokolov, 2012).

Awareness and knowledge of risk management and resilience in the supply chain is one of the key factors affecting the competitive advantage of the chain and its effective functioning. Underestimation or unpredictability of events can lead to serious consequences including disruptions to chain operations. Therefore, the issue of supply chain resilience is a key factor in creating a competitive advantage for SSC (Ribeiro and Barbosa-Povoa, 2018). Frequent disruptions in supply chains without defence mechanisms and the adaptability of the chains lead to a situation where sustainability and SSC strategies are difficult to achieve (Folke *et al.*, 2002; Xiao *et al.*, 2019). It is therefore worth considering the opportunities and impact on the

vulnerability and resilience of sustainable supply chains, in the context of demand uncertainty.

3. Methodology

Select and describe the methodology you have summarized in the previous section. It can be the same as in a previous related work, a modified one you considered more appropriate or a mix of the methods you have analyzed in the literature review section. The increase in research into environmental supply chain practices and the analysis of their impact on the vulnerability of SSC provide an opportunity to seek more targeted operationalization of variables. Consumer research was aimed at investigating whether the factors influencing their purchasing decisions on organic products could (in theory) influence the vulnerability and increase risk of the functioning of sustainable supply chains. Research assumptions:

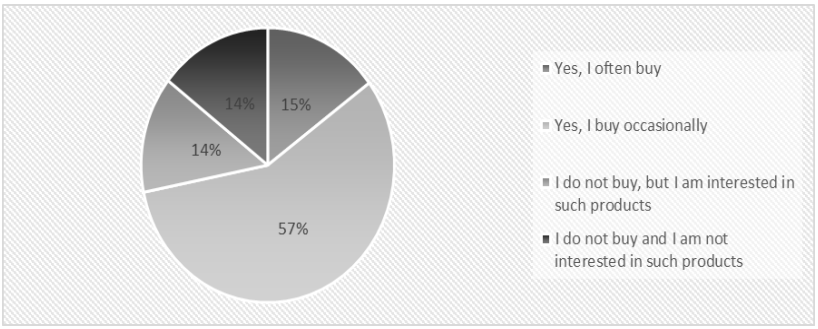
a. Sample size: The research was conducted with the survey questionnaire on the sample of 2127 consumers from Poland (at the age of 19+). This is enough questionnaires for the surveyed population of people in Poland
b. Data Collection: The conducted research was of a quantitative nature. The survey included 8 questions concerning the examined issues and a metric. The questions were prepared because of the Likert scale and open questions were built as well. The study was conducted in February 2020 using random, unrestricted, simple selection.
c. Variables: The article used variables concerning the division into persons buying organic products or not, as well as variables concerning characteristics of organic products, their prices, and barriers to their purchase.
d. Tools. MS Excel software was used to prepare basic statistics and to conduct analysis of variance (ANOVA).

4. Research Results and Discussion

The results of the research help determine how demand uncertainties affect the vulnerability of SSC. First, it will be present the division of the respondents into groups of people who buy, sometimes buy, only think about it, or do not buy organic products will be presented. This division (shown in Figure 1) shows that over 70% of the respondents often or sometimes buy organic products. This result will be used for further analysis of these groups and their possible differentiation in terms of significance of aspects related to ecological supply chains. Further analyses were carried out for the differences between the groups in Figure 1 except for the group that does not buy and is not interested in buying organic products. Figure 2 shows how the answers to the question of what the characteristics of an organic product should be, divided into the above-mentioned groups, developed. No significant differences can be seen here, which is shown by similar thinking about ecology of people buying such products and not buying them. Most people associate ecological

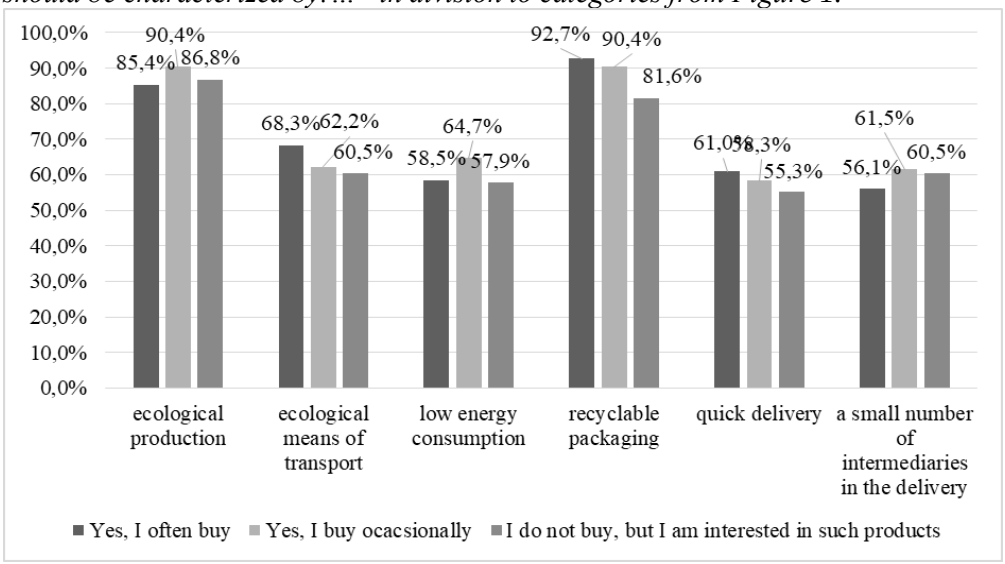
products with ecological production and recycling of packaging Frequency of purchases reduces the uncertainty of demand and consequently a greater chance of success in creating SSC appears. Customer habits toward organic products may contribute to their further resilience to uncertainties in demand.

Figure 1. *Percent of people answering the question: Do you buy organic products food?*



Source: *Authors' calculations.*

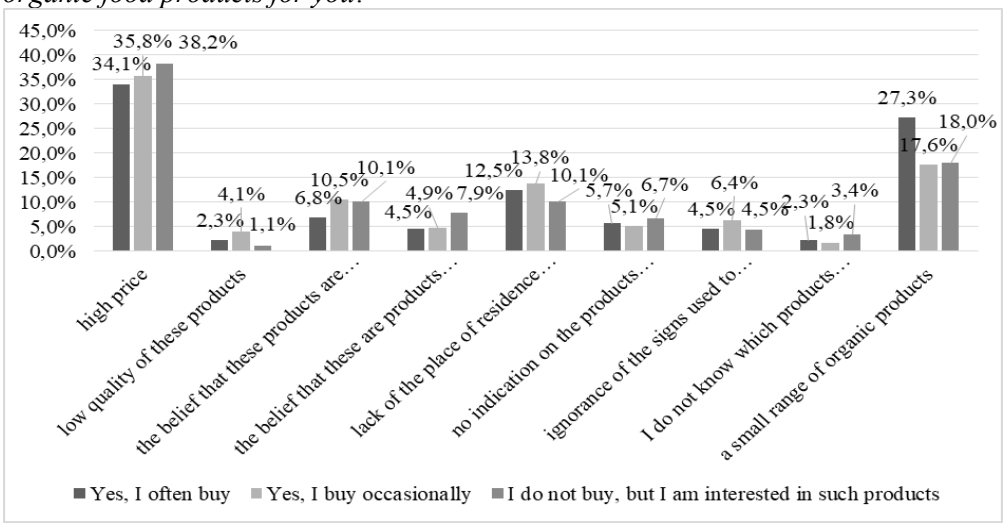
Figure 2. *Number of people answering the question: "An ecological food product should be characterized by:…" in division to categories from Figure 1.*



Source: *Author's calculations.*

In most cases, consumers (those buying often, rarely, or only thinking about buying) pay attention to recyclable packaging and the principles of ecological production (Figure 2). Increasing the level of recyclable packaging and organic production contributes to increasing the resilience of the sustainable chain in these areas, which is important information for potential chain participants.

Figure 2. *Percent of people answering the question: "What is a barrier to buying organic food products for you?"*



Source: *Authors' calculations.*

Figure 3 shows the barriers indicated by the respondents as those that limit buying organic products. Here, in the studied groups (e.g., people who often buy organic products) can be observed, that as a barrier were pointed the lack of these products. This may mean that, despite the fact that there seems to be more and more of these products recently, people who buy them regularly encounter a lack of specific products – this is a factor that affects the uncertainty of demand and can make a chain vulnerable.

However, the most frequently indicated barrier is related to the high price. Other barriers were relatively rarely identified. For those who only think about buying, high price is the biggest barrier, and this is the factor that affects the vulnerability of the chain. Demand may not increase if prices of organic products rise. For occasional buyers, in addition to price and small range lack of place of residence, this is a factor that affects the uncertainty of demand on the one hand and increases the sensitivity of the chain on the other.

Another analysis was supposed to confirm or not the statistical significance of the differences between groups that buy organic products often (A), sporadically (B), or only think about it (C) (Figure 1) in view of the indicated assessment of the importance of the different aspects:

- Social aspects (e.g. health, fashion)
- Ecological aspects (environmental protection)
- Financial aspects (e.g. income, price/quality ratio)
- Economic aspects (e.g. greater control over producers, need for

certification).

Respondents answered questions concerning the degree of influence of these aspects on the interest in organic food products. They rated the respondent's subjective perception on a scale from 1 - no impact to 5 - decisive impact.

The groups of respondents A, B, C differ in terms of assessing the relevance of each of the aspects mentioned above. This finding is partly confirmed by the results of the analysis of variance (ANOVA) presented in tables from 4 to 11, which compare the results of individual groups according to the indicated assessment. ANOVA is used to test the statistical significance of any differences in the analyzed groups (Keselman *et al.,* 1998). It provides no insights into the sizes of the effects and does not indicate which groups caused the differences to be significant (Murphy *et al.,* 2003).

Table 1 shows that the value of F (Fisher) is higher than the theoretical value of the test with a low p-value (below 0.1 but higher than 0.05) at the same time. Therefore, it can be stated that people buy organic products often (A), sporadically (B), or only think about it (C) differ slightly in terms of the assessment of the importance of social aspects for their interest in ecological products. Table 2 shows that there are significant differences between groups A and B, relatively high F-test value with a small p-value, which confirms the hypothesis of differences in terms of the assessment of the importance of social aspects between these two groups.

Interestingly, the analysis did not show any significant differences in scores between groups A and C or between B and C. Customers A and B differ in their assessment of the social aspects, which means that this may be a factor that significantly affects the vulnerability of the SSC. With A and B customers in the SSC, social aspects should be properly presented. This means that differentiating social aspects for consumers need to be identified to reduce the risk of a sustainable SSC functioning. At the same time, social aspects such as health (social campaigns of healthy products) affect the uncertainty of demand.

Table 1. *Analysis of variance of social aspects for all analysed groups A, B, C.*

Source	SS	df	MS	F	p-value	Test F
Groups	6.248103	2	3.124051	2.610531	0.075635	3.034414
Error (Within)	280.0304	234	1.196711			
Total	286.2785	236				

Source: *Authors' calculations.*

Another analysis showed that there was no differentiation between the A, B, and C groups in the ecological aspects that influence the possible purchase decision of organic products. The lack of differentiation was observed in comparison of groups together (Table 3) and in pairs (Table 4).

Table 2. *Analysis of variance of social aspects for pairs: A and B, A and C, B and C.*

Pair	F	p-value	Test F
A and B	77.72741	<.0001	3.851339
A and C	0.560805	0.456217	3.965094
B and C	1.261443	0.262766	3.889839

Source: *Authors' calculations.*

Table 3. Analysis of variance of ecological aspects for all analysed groups A, B, C.

Source	SS	df	MS	F	p-value	Test F
Groups	0.76757	2	0.383785	0.38953	0.677814	3.034414
Error (Within)	230.5489	234	0.985252			
Total	231.3165	236				

Source: *Authors' calculations.*

Table 4. Analysis of variance of ecological aspects for pairs: A and B, A and C, B and C

Pair	F	p-value	Test F
A and B	0.671987	0.41335	3.889096
A and C	0.510434	0.477111	3.965094
B and C	0.036162	0.849381	3.889839

Source: *Authors' calculations.*

It can be assumed that in the absence of significant differences between the assessments of the groups, environmental aspects will have the same effect on the vulnerability of the SSC.

Similar conclusions can be drawn from Table 5. No differentiation between groups A, B, and C together from assessment of financial aspects that affect the purchase of organic products (p-value > 0.1). However, looking at the results of the pair-by-pair comparisons between the groups (Table 6), significant differences in the assessment of economic aspects between groups A and B as well as A and C can be seen. However, this indicates that people who buy more often organic products are more likely to pay attention to the price and quality of these products.

Table 5. *Analysis of variance of financial aspects for all analysed groups A, B, C.*

Source	SS	df	MS	F	p-value	Test F
Groups	3.930678	2	1.965339	2.010346	0.136249	3.034414
Error (Within)	228.7613	234	0.977612			
Total	232.692	236				

Source: *Authors' calculations.*

Table 6. *Analysis of variance of economic aspects for pairs: A and B, A and C, B and C.*

Pair	F	p-value	Test F
A and B	4.129912	0.043474	3.889096
A and C	3.000175	0.087366	3.968471
B and C	0.084442	0.77168	3.890348

Source: *Authors' calculations.*

It can be assumed that in the absence of significant differences between the assessments of the groups, the financial aspects will affect the vulnerability of the SSC in the same way.

Significant differences between the assessments of groups A, B and C came out when they are assessing the economic aspects (Table 7). As in the case of the economic aspects, the biggest differences are between groups A and B as well as A and C (Table 8). This also means that the group of people who often buy organic products most often pays attention to the certificates.

Table 7. *Analysis of variance of economic aspects for all analysed groups A, B, C.*

Source	SS	df	MS	F	p-value	Test F
Groups	12.80651	2	6.403254	6.039637	0.00277	3.034414
Error (Within)	248.088	234	1.060205			
Total	260.8945	236				

Source: *Authors calculations.*

Table 8. *Analysis of variance of economic aspects for pairs: A and B, A and C, B and C. Source: Authors' own calculation*

Pair	F	p-value	Test F
A and B	5.642293	0.020088	3.968471
A and C	12.81398	0.000433	3.889096
B and C	0.095019	0.758225	3.890348

Source: *Authors' calculations.*

5. Discussion, Limitations and Conclusions

The conducted research indicates low purchasing awareness of consumers of organic products. Despite the declarations of buying such products, the respondents most often were willing to pay only 10% more for this type of product (30% if the maximum sum of production, storage, and transport costs is taken into account), while the current market prices are much higher than these values, and the respondents pointed in the surveys to high prices as the basic problem of buying organic food. This may indicate that the existing trends in the consumption of organic products are strong enough to distort the economic calculation of the price relationship between organic and non-organic products. The relationship between price and consumer income may become more and more important in this respect.

The significance of the existing trends is confirmed by the fact that packaging and its labelling are significant in making purchase decisions in this respect (see Figure 2).

An interesting aspect is related to the initial diversification in the scope of tendency to incur higher costs of production, transport, and storage of organic food. Lack of homogeneity indicates increased vulnerability of this type of SSC and building resilience through its proper design (in accordance with the expectations of the consumer of a given product group). The respondents indicated that they can pay a maximum of 10% more, which would include costs related to ecological production, transport, and storage. Consumers will choose an organic product if its price does not increase by more than 10% (and even 20%) compared to the price of a conventional product. This increases the risk of demand uncertainty, which means that it is impossible to invest in ecological logistic solutions (production, transport, storage). The risk and vulnerability of the SSC in this respect is significantly increased.

Limitation was to examine only the demand side by omitting the supply side of the chain. The authors plan to examine the supply side in the next stage of the research. It is also required to build a wider catalogue of uncertainty factors together with the analysis of interdependencies between factors and dedication of selected (most frequently occurring) factors to the specificity of the SSC. The greater the uncertainty of demand and greater the hesitation of buyers, the less certainty and willingness to buy even at a higher price (associated and consequence with higher costs), the greater the impact on the vulnerability and uncertainty of the supply chain. Especially in relation to sustainable chains, which are more cost-intensive and thereby more vulnerable to external factors.

The identified research problem was an interesting study of scientific exploration. The research objectives achieved allowed to identify sources of uncertainty and vulnerability in sustainable and supply chains. Different groups of consumers who declare to buy organic products in the context of SSC vulnerability have been identified. The analysis of the dependence of the criteria of uncertainty of the SSC functioning in the context of the knowledge of consumer preferences was made. The considerations allowed for a better understanding of the impact of demand uncertainty on the vulnerability of an SSC. Empirical research can be a guide to identifying and determining uncertainty factors for buyers of organic goods and, consequently, for SSC managers in designing a resilient supply chain. The research allowed to determine whether consumers are interested in buying organic products.

Three main groups were identified: frequent buyers, rare buyers, and just those thinking about buying. The barriers to purchasing in these groups were presented and the characteristics an organic product should have according to the respondents and how it affects the vulnerability of the SSC were shown. Research is also presented on how these groups differ from each other in view of the indicated

assessment of the importance of the different aspects: social, ecological, financial, and economic aspects of SSC.

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