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Triple bottom line aspects and sustainable supply chain resilience: A structural equation modelling approach

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The purpose of this paper is to investigate which of sustainability elements, in the context of triple bottom line (TBL), are used to build sustainable supply chain resilience. This paper presents a new body of knowledge and contribution to the literature by relating the triple bottom line (TBL) context to the building of sustainable supply chain resilience using structural equation modelling. The research were used to understand that individual sustainability factors matter and play a role in the context of supply chain resilience. A survey questionnaire was designed to collect this data from the research respondents. To statistical analysis was first Confirmatory Factor Analysis (CFA) conducted and used, then for the analysis and interpretation structural equation model. The findings indicate that individual sustainability factors matter and play a role in the context of supply chain resilience. A number of previous studies have developed broad catalogues of sustainability factors influencing supply chains, however, to date no convincing evidence has been presented as to which of the range of elements identified, and how they influence supply chain resilience building. Despite the large number of publications on sustainable supply chain and resilience building, there is still a gap and lack of proper consideration of TBL-related criteria as elements that can determine mechanisms for building supply chain resilience in the context of sustainable development. This paper operationalizes a using the structural research model to using a structural research model to investigate how and in which relationships the different elements of the triple bottom line influence the resilience of supply chains.

KEYWORDS

triple bottom line (TBL), supply chain resilience, structural equation modelling (SEM), sustainable supply chain (SSC), organic product

1 Introduction

Supply chain managers attempt to find ways to mitigate potential risks, and to rise to supply chain challenges via the implementation of innovative ideas, policies, and strategies. For this purpose, they use dynamic responses and adaptations to changing market realities. Disruptions can range from economic and/or natural causes (such as financial crises, terrorist attacks, disease, fuel crises, political uncertainty, earthquakes, and other phenomena affecting the external environment). Each of these has a negative impact on supply chain operations (Mandal, 2012; Massari et al., 2021), and they may apply to different levels, from the operational to the strategic (including equipment failures or breakdowns, production delays and obstacles, and natural hazards and

pandemics) (Lopes et al., 2022). Crisis situations have a direct impact on the organization's ability to continue its operations. Disruptions in the chain can be two-fold. They may be the result of external or internal factors (Soni et al., 2014), and of ongoing globalisation processes, and the consequences of these factors increases the vulnerability of chains (Ponomarov and Holcomb, 2009). Therefore, in recent years, new risk management concepts have been increasingly introduced to mitigate the problems that are caused by disruptions that occur (Schmitt and Singh, 2012).

The key to managing sustainable supply chains and the risk of disruptions is to understand the vulnerabilities that exist and to implement solutions for building increased resilience into the chains. It is also important that solutions are created in accordance with the principles of sustainable development, which become the determinants of the actions that are taken. This is also reflected, in practice, in the implementation of the individual factors of the triple bottom line (TBL) into supply chains (Dubey et al., 2017; Dubey et al., 2019).

On the other hand, the context and pressure to move towards sustainable economies and environmentally neutral processes, and the creation of sustainable and closed-loop chains makes it necessary to implement these activities and solutions within supply chain organizations. The traditional approach toward supply chain management, based on the cost, quality, and time paradigm, is no longer relevant. The strategy of sustainable development should be added to the basic tasks and challenges of the chain. For many years, this issue has been referred to in the literature, and is increasingly being recognised as one of the basic elements of supply chain management (Hassini et al., 2012; Dai et al., 2021; Soltanmohammadi et al., 2021; Tsai et al., 2021; Seuring, et al., 2022). Market demands and the economic situation have led to the environmental and social performance of a company becoming as important as its economic performance, from the customer's point of view (Tsai et al., 2021).

It is becoming necessary to build supply chains that are increasingly resilient to risk factors, while implementing sustainability principles. This means that there is now a different dimension for supplying chain management, one that focuses on sustainability, and which is vulnerable to unexpected and unforeseen disruptions (Mari et al., 2014). In this situation, the fight against disruptions comes to the fore and often means the abandonment of plans and actions to, for example, implement sustainability aspects. A trade-off must therefore be found between supply chain disruption and sustainability. The latter should look for opportunities to build resilient systems and to support a change in business strategy that allows for sustainable yet resilient supply chains. Sustainability is the goal, and in addition, opportunities should be sought to build their resilience precisely through these aspects.

The main objective of this study is to examine if and how these aspects of sustainable development influence the resilience of supply chains, using empirical research conducted in medium and large enterprises in Poland representing various industries. The study also aims at presenting recommendations and conclusions, as well as postulates for the future, indicating which elements and aspects of sustainable development have an influence on building the resilience, not only of a company, but also of the entire chain, and above all, on implementing and developing a sustainable supply chain strategy via the application of the indicated sustainability criteria. Strategies that have been applied in chains, more than ever, are focused both on the aspect of sustainability and on the aspect of resilience. The observed scientific activity in this area, but also the practical solutions, perfectly reflect the importance and essence of the considerations that have been undertaken, while at the same time filling the identified research gap.

The motivation for undertaking the indicated research was the identified research gap, which can be defined as follows: *A lack of research on sustainability aspects in supply chains operating in Poland has been noted, and even fewer studies focus on building the resilience of sustainable chains using sustainability criteria.*

The paper is structured as follows: an introduction that provides a background on the relevance of building resilience in supply chains, especially considering the sustainability aspects and the implementation of sustainable chain strategies into business solutions. This is followed by a critical review of the literature, including: sustainable supply chains, the essence of the resilience and the vulnerability of the chains, linking the phenomena of resilience, vulnerability, and sustainability aspects in the supply chain area in light of the existing literature, developing and justifying the purpose of the research through the presentation of the research gap, the research methodology, the research results, and the findings, where aspects of the novelty of the considerations and contributions to the development of the science and discussion are pointed out. The discussion concludes with a summary and recommendations for the scope of further research in this area. The aim of the article is to identify, using a structural equation model, the sustainability factors affecting the resilience of supply chains. Based on the literature analysis, categories of factors corresponding to each sustainability category were identified, the most suitable factors were selected for empirical study. They were then considered in terms of their impact on supply chain resilience. The identified research gap allowed the following research questions to be posed: *Have environmental, social and economic dimensions of sustainability had an influence on the supply chain resilience? Does each sustainable dimension have the same influence on supply chain resilience?*

2 Literature review

2.1 Resilience and sustainability in the supply chain

Resilient supply chains are part of a strategy that supports their fluidity and reliability (Ryczyński and Tubis, 2021). The link between resilience and social–ecological systems is not new in the literature. There is ample scientific evidence indicating that researchers are interested in this area (Derissen et al., 2011). Responding effectively to supply chain disruptions in the currently fast-changing and competitive market environment can be a tool to protect against bankruptcy, closure or non-competitive chains. One element supporting such responses may be the need to adopt sustainability concepts at an operational level (Ramezankhani et al., 2018).

The literature is rich with considerations of sustainable supply chains, although, as rightly pointed out by Pagell and Shevchenko (2014), the true face and principles of sustainable development are not yet implemented in the chain, and they are an aspiration for many (Seuring, et al., 2022). It is possible to see progress in this area,

and many elements have already implemented. The topic is well-known and described. However, its high global relevance should be pointed out (Men et al., 2023). Referring to the work of Seuring and Müller, (2008), and of Seuring et al. (2022), it should be pointed out that the interest in sustainable supply chains in a theoretical context concerns the management of stakeholders (who exert pressure on the use of sustainable factors in supply chain operations) and of pressures and incentives, which also capture internal drivers and barriers, as well as the relationship of a focal company and its (multiple-) tier suppliers and the related management practices, and of supply management and its related processes. One of the objectives of a sustainable supply chain is to increase economic and environmental value for the various stakeholders in the chain (Yontar and Ersöz, 2020). With a focus on supplier selection and evaluation, the results are categorised into the risk management and performance management of the supply chain, thereby focusing on the outcomes. Sustainable supply chain management is the management of resources, activities, information, and capital to maximise supply chain profitability while minimising the environmental impacts of supply chain operations and enhancing social welfare (Hassini et al., 2012). Therefore, organisations operating in supply chains, in order to meet market challenges, increasingly pay attention to new concepts that can be implemented in the chain area, which at the same time become critical elements for their survival and their further development (Min and Kim, 2012). It is recognised that in the long term, following the path to social improvement and producing environmentally friendly products will certainly strengthen businesses economically (Tsai et al., 2021). Some of the tools identified may additionally become guarantors for the resilience of chains.

In the context of these deliberations, the most relevant element, apart from the implementation of sustainability principles and individual elements, is the aspect of risk management, through which the resilience of supply chains can be built. In terms of research on sustainable supply chain risks, a multi-faceted analysis needs to be undertaken (Lima et al., 2021). Supply chain sustainability plays a mediating role in the process of supply chain resilience affecting supply chain performance (Zhu and Wu, 2022; Zhang et al., 2023). The 3BL aspects, understood as being the incorporation of social, environmental, and economic factors, should be implemented into supply chain strategies to build the resilience of the latter, as well as moving towards more pro-environmental and social, but also more economical supply chain strategies. However, it is worth noting that there is increasing talk of integrating ESG indicators into the performance evaluation of green or sustainable supply chains. (Sardanelli et al., 2022; Zeng et al., 2022). This aspect should also be taken into account when considering chain resilience issues.

2.2 Key assumptions of supply chains resilience

Building resilient supply chains is an extremely challenging task, as it involves, among other things, mitigating risk, and an extremely large number of different frameworks and tools are present for the evaluation and management of risks (Cha et al., 2008). Supply chain resilience is defined as the ability to proactively design and plan a supply chain network, and to anticipate unexpected (negative) disruptive events in order to adaptively respond to disruptions (Ferreira et al., 2021). Resilience is defined as the ability for individual supply chain participants and the network as a whole to recover from disruptions and to restore operations and performance to an even better state than in the pre-crisis era (Tsolakis et al., 2021). Supply chain operations are subject to constant change and uncertainty. Resilience is therefore a key factor (Pettit et al., 2019) for ensuring that chains operate smoothly and efficiently. The structure and strategy of the chain must be organised in such a way as to be prepared to react quickly to unexpected events (Pavlou and Manthou, 2008; Ponomarov and Holcomb, 2009). The resilience of chains has an influence on the size of both the companies and the overall structure of the chain (El Baz and Ruel, 2021). Supply chains need to be resilient in order to thrive in the rapidly changing environment that surrounds them (Zhang et al., 2022), Supply chain risks are typically classified as being operational and disruption risks (Sawik, 2011). The literature indicates that one of the most effective methods for dealing with interference threats is to design resilient networks. At the same time, risk management and resilience are strategically viewed (Hervani et al., 2022). Supply chain resilience can be defined as the specific ability of this structure to absorb and to recover from disruption, in order to deliver upon promises that have been made to customers within a reasonable timeframe (Ponomarov and Holcomb, 2009).

Disruption in the supply chain is a natural occurrence, and it is more or less likely to occur and to have a greater or lesser impact on supply chain operations (Sodhi and Tang, 2012). We can talk about natural hazards (earthquakes, floods, or the recent COVID-19 pandemic), but also about those that are associated with demand volatility, cost uncertainty, equipment failure, or labor shortages. Usually, after an appropriate response and the elimination of risks or disruptions, chains become stronger, more resilient, and more competitive in the marketplace (Zavala-Alcívar et al., 2020a). The complexity of the supply chain network requires greater resilience (Lopes, et al., 2022).

The main drivers of resilience in chains includes: collaboration, the redesign of the supply chain to respond quickly to disruptions, agility, innovation, flexibility, visibility, and sharing and trust (Juttner and Maklan, 2011; Ferreira et al., 2021).

2.3 Linking sustainable supply chain strategy aspects to resilience issues

Based on the literature, has been presented a set of factors that can be linked to both resilience and sustainability (shown in Table 1).

There is still a lack of comprehensive research relating to the impact of sustainability on supply chain resilience (Fahimnia and Jabbarzadeh, 2016). As Suryawanshi et al. (2021) indicated in their analysis, there is little research on the implementation between these critical concepts, particularly in the context of supply chain design. They point to research that has been conducted in this area (analysis in Table 2).

2.4 Literature review of sustainability aspects of chain resilience

In the existing research, the lack of a broader view on the design and management of resilient supply chains with sustainability

TABLE 1 Factors affecting the sustainability and resilience of the supply chain.

Type of connection	Factor
Economic	Operational cost, Transportation cost, Ordering cost, Defective rate
Environmental-Economic	Minimum energy consumption, Minimum (raw) material usage, Water usage, Capability of using green technologies, Technology level
Environmental- Economic-Social	Capability of R&D
Environmental	Pollution production, Usage of toxic substances, Environmental management systems, Reduction of solid waste
Social	Customer satisfaction, ISO 14001 certification, Job security, Occupational injury and illness, Training education and Community Development, Worker safety and labour health, Job opportunity, Funding special projects (school, hospital, etc.)
Economic- Resilience	Delivery lead time
Resilience	Institutional distance between the buying firm and its supply base, Buffer capacity

Source: based on: Ponomarov and Holcomb (2009), Warmbier et al. (2022), Negri et al. (2021), Manurung et al. (2023), El Korchi (2022).

TABLE 2 Analysis of issues raised in the literature on resilience and sustainability of supply chains.

Area of research	Author (s) and title of article
Exploring the relationship between the concepts of resilience and sustainability in the context of supply chain design	• Nandi et al. (2021) • Ardakani et al. (2020) • Lohmer et al. (2020) • Rajesh (2020b) • Jabbarzadeh et al. (2018) • Mathiyazhagan et al. (2018) • Ivanov (2018) • Zahiri et al. (2017) • Perrings (2006) • Fiksel (2003)
strategies of sustainably-resilient supply chain	• Mehrjerdi and Shafiee (2021) • Ivanov (2020) • Murtagh et al. (2020) • Rajesh (2020a) • Zavala-Alcívar et al. (2020b) • Pavlov et al. (2019) • Ramezankhani et al. (2018) • Rajesh (2018) • Jabbarzadeh et al. (2018)
performance management framework to assess SC performance from resilience and sustainable viewpoints	• Ramezankhani et al. (2018)
viable SC is built on the foundation of agile, resilient, and sustainable perspectives	Ivanov (2020)
sustainably resilient SC of the construction domain	Murtagh et al. (2020)
systematic literature review on studies combining resilient and sustainable concepts	Zavala-Alcívar et al. (2020a)

Source: own elaboration on the basis of: Suryawanshi et al., 2021.

factors has been indicated. The impact of risk mitigation techniques on the environmental and social sustainability of the business environment is often not explored. It therefore becomes important to explore and to link the objectives of sustainability (economic, environmental, and social) and resilience with the objective of maximising the implementation of a strategy for, for example, a sustainable supply chain with its economic objectives. There is no doubt that demand uncertainty, flexibility and

deliverability, production, or transport disruptions all need to be modelled in such a way as to minimise the negative environmental effects and costs of the whole chain. On the basis of the literature, it is clear that organisations alone cannot survive a wide range of disruptions (Bhamra, et al., 2011), to which they are exposed; therefore, resilience strategies need to be developed to counteract this, referring to a set of complex actions involving cooperation, transparency and communication (Gunasekaran et al., 2015). Therefore, it is necessary to know exactly what factors influence resilience, and how they exert their influence. There are many approaches to this in the literature, ranging from how to respond to unpredictable weather events (de Sá, et al., 2019), to political changes (Hendry, et al., 2018). Undoubtedly, of recent and great importance is the context of COVID-19 and its impact on the operation of chains, as this is a challenge to which companies have had to respond accordingly (Silva et al., 2021). Increased resilience can be seen in local chains that base their commercial transactions on local markets (Thilmany et al., 2021), thereby making themselves independent of dangerous situations and building up their resilience, as well as in the size of companies (El Baz and Ruel, 2021), because, considering various factors, it is accessibility that matters in terms of resilience development. In addition to the creation of a new sustainable supply chain strategy, resilience-building concepts should be adopted and implemented to mitigate the disruptions that can occur in the supply chain (Hosseini-Motlagh, et al., 2020). Combining the concepts of sustainability and resilience and implementing them into the structure of the chain can contribute to its optimisation (Kaur et al., 2020). The strategic orientation of the supply chain processes towards social sustainability creates a holistic approach leading to the achievement of both socio-economic and socio-environmental sustainability goals (Townsend, 2020). In the recent scientific literature, the topics most frequently raised concern companies that conduct their business activities more heavily on the environmental sustainability front than on the social sustainability side (Porteet al., 2019). It is becoming important for companies in the supply chain to consider and to highlight the social side of sustainability in their operations, as its omission can have disastrous consequences. It is increasingly apparent that investors are supporting and selecting organisations whose long-term performance can be assessed through an investigation into their environmental, social and governance (ESG) considerations, or through their socially responsible investment (SRI) positions, or by assessing both perspectives (Hervani et al., 2022). In the supply chain context, linking the operational level of decision-making and the tactical and strategic levels can improve social sustainability. In relatively stable economic times, organisations can use non-traditional methods of valuing environmental aspects to monitor socio-economic and socio-environmental performance (Johansson, 2016). In unstable, unpredictable and disruptive times, sustainable companies tend to adopt an ambivalent attitude, reducing their efficiencies and expected economies of scale, and allowing sufficient redundancy—in the form of coordination, cooperation and flexibility—in their supply chain operations to maintain socio-economic and socio-environmental sustainability (Bui et al., 2021).

Referring to the literature, and by linking the two concepts of resilience and sustainability, Rajesh (2021) conducted a systematic literature review considering together the aspects of sustainability and resilience, and pointed out that Papadopoulos et al. (2017) have proposed a theoretical framework for explaining resilience in supply chains to achieve sustainability. Additionally, Fahimnia and Jabbarzadeh (2016) formulated in their considerations a multi-actor decision-making model for achieving sustainability and resilience in supply chains. Ivanov (2018), on the other hand, analysed the ripple effects in supply chains, with sustainability factors for the design of resilient supply chains. From another point of view, Scholten and Fynes (2017) discussed the need for risk management and resilience to achieve sustainability in complex supply chains. Based on research (Rajesh, 2021), it can be said that research in this field has been ongoing for many years, but it is still insufficient. Already, in 2009, an integrated framework for the resilience and sustainability of offshore activities was proposed (Rosič et al., 2009; Pettit et al., 2019), and much attention has been given to food supply chains as their resilience is dependent upon many factors, including weather, while at the same time they are relatively advanced in the implementation of sustainability principles, due to the expectations of their customers (Leat and Revoredo-Giha, 2013; Manning and Soon, 2016; Stone and Rahimifard, 2018). The issue can also be approached in a different way. By referring to studies on the sustainability–resilience relationship at the supply chain design level (Fahimnia and Jabbarzadeh, 2016; Ivanov, 2018), resilience in the context of trust was addressed in the social aspect, proposing a framework for resilience, with the consideration of trust and behavioural uncertainty (Dubey et al., 2017). In another view, it was suggested that the theoretical framework and the explained resilience in supply chain networks could be investigated for the development of sustainability. Papadopoulos et al. (2017) also examined a supply chain design model for robustness in order to explore the relationship between greening and resilience. Fahimnia et al. (2018) also assessed the performance of supply chains, considering sustainability and resilience viewpoints. Ramezankhani et al. (2018), Ivanov (2020), and Rajesh (2021) observed different management frameworks for improving sustainability and resilience. Negri et al. (2021) and Marchese et al. (2018) studied disruption propagation, considering the factors of sustainability for designing resilient supply chains. Ivanov (2018), Zahiri et al. (2017), Sabouhi et al. (2021), and Mari et al. (2014) explored the phenomenon of collaborative resilience for sustainability, considering in-depth case-based studies. Aggarwal and Srivastava (2019) and Duong and Chong (2020) envisioned future opportunities for advancing the theory of resilience towards long-term sustainability. Redman (2014) and Pettit et al. (2019) pointed out the need for integrating resilience and sustainability in supply chains to improve competitiveness (Carvalho et al., 2011; Azevedo et al., 2013; Govindan et al., 2015; Zavala-Alcívar et al., 2020a; Zavala-Alcívar et al., 2020b). Based on various considerations (Labuschagne et al., 2005), it should additionally be stated that in the context of the social aspect, internal human resources are activities of social responsibility that focus on employees and their employment conditions, including job stability, work practices, health and safety, and capacity building. The external population focuses on activities that are related to the availability of new human knowledge and services, productive assets and services, and social and economic wellbeing that are

external to the organisation. Stakeholder participation focuses on the organisation's relationship with its internal and external stakeholders by enabling information sharing and including stakeholders in decision-making. Macro-social issues and concerns focus on the wider environmental and financial impacts that arise from business activities, including GDP growth or the creation of new environmental legislation. It therefore seems appropriate to examine various aspects of sustainable development (economic, environmental, and social) and resilience (network and supply chain resilience) objectives with purpose of the maximization of this element.

3 Material and methods

The process of data collection is one of the most important components of the research methodology. A quantitative approach to data collection was adopted with deductive reasoning.

Furthermore, we explore the interdependencies and relationships between individual elements, and the mutual influences of individual factors in the context of building resilience, and the result of these considerations is the proposal of a structured model for building resilience using the principles of sustainable development. The structural equation method is useful in the context of finding relationships between factors affecting the supply chain, among others Sulehri et al. (2023) analyzed the data using structural equation modeling and a partial least squares technique to find that disruption risk, research and development investment, and firm performance all improve supply chain performance. Whereas Maqsood et al. (2022) determine the factors that influence green supply chain management adoption in SMEs and the moderating effect of clean innovation technology for sustainable production and consumption. Activities are conducted so that in the future, there is appropriate management of the individual elements that will be the driving forces and success factors, and at the same time, the elements that characterise the resilience of sustainable supply chains.

The research tool, i.e., the questionnaire, was developed on the basis of previously validated information, and sustainability factors were found in the literature that influence or that are used in supply chains, according to our assumptions (referring to the criteria of building resilience and of focusing on a sustainable supply chain).

A survey questionnaire was designed to collect these data from the research respondents. A professional research company specializing in computer-assisted telephone interviewing conducted the survey. It was conducted using computer-assisted telephone interviewing (CATI) and a supplementary research technique—a web-based survey (CAWI)—to be completed by the respondent. The company contacted farmers, processors, stationery, and online stores selling organic products (including natural cosmetics and household chemicals). The study sample consisted of 700 enterprises from Poland. For the research presented, the constructed questionnaire was divided into two main sections. The first section involved company information, including the type, size, and location of the company. The respondents were asked to score their answers, considering a Likert scale of 1 to 5 and the quantitative questions. The five-point Likert scales are a highly acceptable and reliable scale for questionnaire surveys (Dillman et al., 2014). Table 3 summarizes the demography of the respondents and the received responses.

TABLE 3 Profiles of responding companies.

Distribution variables	Percentage (%)
Company size (number of employees)	
sole proprietorship	37
from 1 to 9 persons	43
from 10 to 49 persons	12
from 50 to 249 persons	7
from 250 and more persons	2
Voivodeship	
Lower Silesia	4
Kuyavia-Pomerania	4
Lublin	8
Lubusz	3
Lodzkie	4
Lesser Poland	5
Masovia	16
Opole	1
Subcarpathia	9
Podlassia	10
Pomerania	6
Silesia	3
Kielce	5
Warmia-Masuria	10
Greater Poland	7
West Pomerania	7
Role	
Producer (farmer)	54
Manufacter of organic goods	29
Stationary/internet store (retailer)	17

Based on the literature survey (Ramezankhani et al., 2018; Negri et al., 2021; Warmbier et al., 2022) and the experiences of the authors, it was assumed that a model would be investigated to examine the impact of the classical elements of a sustainable supply chain on its resilience (Table 4).

4 Results

4.1 Structural equation modelling

The research used a measurement model to identify the number of factors in the latent variables, as well as a structural model showing the effect–cause relationships between the variables. The existence of correlations between the theoretical exogenous constructs was also

TABLE 4 Item pool included in the research.

Social sustainability
(SOS1) Diversity, equal opportunity and discrimination
(SOS2) CSR
(SOS3) Motivation program for workers
Economic sustainability
(ECS1) Impact of the economic environment
(ECS2) Impact of taxes
(ECS3) Fraction of transportation costs in total costs
(ECS4) Fraction of production costs in total costs
(ECS5) Fraction of recycling costs in total costs
(ECS6) Fraction of storage costs in total costs
Enviromental sustainability
(ENS1) Use of pro-environmental solutions in the company in the area of transport
(ENS2) Use of pro-environmental solutions in the company in the area of storage
(ENS3) Use of pro-environmental solutions in the company in the area of production
(ENS4) Use of pro-environmental solutions in the company in the area of distribution
(ENS5) Use of pro-environmental solutions at your partners (in supply chain) in the area of transport
(ENS6) Use of pro-environmental solutions at your partners (in supply chain) in the area of storage
(ENS7) Use of pro-environmental solutions at your partners (in supply chain) in the area of production
(ENS8) Use of pro-environmental solutions at your partners (in supply chain) in the area of distribution
(ENS9) Percentage of product returns
(ENS10) Impact of ecological balance sheet
Supply chain resilience
(SCR1) Year-on-year percentage change in sales
(SCR2) Percentage of market share
(SCR3) Customer growth rate from last year
(SCR4) Number of clients
(SCR5) The impact of our actions on the actions of our partners in the chain
(SCR6) Company's activities in the area of innovation

investigated. First, Confirmatory Factor Analysis (CFA) was conducted, based upon which a set of variables (specific questions in the survey) was extracted that was most able to explain the latent variables. Confirmatory factor analysis (CFA) was deemed a primary step towards the application of the SEM model, and it was used to decide how the proposed model fits the data (Jenatabadi and Ismali, 2014). SEM methodology has been successfully used to show the impact of various aspects of the supply chain on its efficiency, e.g., in Dey et al. (2021) or Zhang et al. (2022). With CFA, any item that does not fit the measurement model due to low factor loading should be removed. CFA needs to be performed for every latent construct that is involved in a model. The confirmatory factor analysis (CFA) technique was convincingly applied in many cases, because it allows for the specification of any number of factors required in the data, and it identifies which measured variables are related to their corresponding latent variables. On the basis of the outcomes, CFA is used to verify or to refuse the measurement theory.

Table 5 presents the confirmatory factor analysis of a measurement model (with four latent constructs representing the three classic elements of a sustainability supply chain—social, environmental and economic sustainability, and the resilience of the supply chain) that was conducted using Statistica (Statsoft v. 13). This analysis indicated that the model fit the data reasonably well.

The basis for factor inclusion was that the eigenvalue should be greater than one, the total variance explained should be greater than

TABLE 5 Outer loadings with reliability indicators.

Latent constructs	Indicators	Outer loadings	Cronbach's alpha
Social sustainablity	SOS1	0.73[a]	0.81
	SOS2	0.72[a]	
	SOS3	0.67[a]	
Economic sustainablity	ECS2	0.73[a]	0.61
	ECS3	0.76[a]	
	ECS5	0.71[a]	
	ECS6	0.82[a]	
Enviromental sustainablity	ENS1	0.86[a]	0.80
	ENS2	0.93[a]	
	ENS3	0.77[a]	
	ENS4	0.81[a]	
	ENS5	0.87[a]	
	ENS6	0.91[a]	
	ENS8	0.93[a]	
	ENS9	0.77[a]	
	ENS10	0.66[a]	
Supply chain resliance	SCR1	0.85[a]	0.73
	SCR2	0.86[a]	
	SCR3	0.84[a]	
	SCR4	0.88[a]	
	SCR5	0.69[a]	

[a]Indicating significance at 1%.

50%, and that the factor loading of each item should be greater than 0.50. For the learning and growth performance indicators, the eigenvalue of each factor was above one (3.20, 2.19, 1.82, and 1.22), which accounted for 61.23% of the total variance. The four analysed factors were measured using 26 items, of which 5 items (one from social sustainability, two from economic sustainability, one from environmental sustainability and one from supply chain resilience) were discarded from the list due to factor loadings of <0.50.

4.2 Reliability

The quality of a survey can be measured by inspecting its reliability (Paul and Maiti, 2008). The reliability of the data can be checked using Cronbach's alpha. As a rule of thumb, if $\alpha \geq 0.7$, then the solutions are considered risk free, but 0.6 is considered to be acceptable in the case of an exploratory study (Nunnally, 1978; Thun, 2010). Most often, reliability is determined by analyzing the test's internal consistency using Cronbach's Alpha (α). Cronbach's alpha will be high if the variance of the entire scale is much greater than the sum of the variances of the individual items. A high variance of scale items is inadvisable, as it may indicate large measurement errors. The formula for Cronbach's alpha, a measure of reliability, of the test's internal consistency is of the form:

$$\alpha = \frac{k}{k-1} \cdot \left(1 - \frac{\sum_{i=1}^{k} s_i^2}{s_c^2}\right)$$

Where.

α— Cronbach's alpha

k— number of test items

s^2_c— total variance of the overall test results

s^2_i— variance of test items

In our study, Cronbach's alpha for all the constructs was greater than 0.6 (in one case) and greater than 0.7 (in three cases), which is acceptable (George and Mallery, 2016).

The use of confirmatory factor analysis allowed us to determine which of the observable variables (individual questions) most strongly defined the related constructs—exogenous and endogenous latent variables, which resulted in their further reduction. Only those variables that correlated most strongly with a given latent factor were accepted for structural model estimation.

TABLE 6 Structural parameters of the analyzed structural model.

Path	Path coefficiant	Statistic t
SOS1- > Social sustainability	0.792*	33.600
SOS2- > Social sustainability	0.838*	36.591
SOS3- > Social sustainability	0.638*	23.334
ECS2- > Economic sustainability	0.213*	4.847
ECS3- > Economic sustainability	0.372*	9.048
ECS5- > Economic sustainability	0.737*	18.111
ECS6- > Economic sustainability	0.653*	16.513
ENS1- > Environmental sustainability	0.176*	4.661
ENS2- > Environmental sustainability	0.870*	80.639
ENS3- > Environmental sustainability	0.912*	108.717
ENS4- > Environmental sustainability	0.766*	45.273
ENS5- > Environmental sustainability	0.935*	128.395
ENS6- > Environmental sustainability	0.064**	1.658
ENS8- > Environmental sustainability	0.199*	5.325
ENS9- > Environmental sustainability	0.162*	4.257
ENS10- > Environmental sustainability	0.245*	6.693
SCR1- > Supply chain resilience	1.000*	-
SCR2- > Supply chain resilience	1.079*	21.962
SCR3- > Supply chain resilience	0.464*	11.132
SCR4- > Supply chain resilience	0.446*	10.562
SCR5- > Supply chain resilience	0.157*	3.315
Social sustainability - Economic sustainability	0.249*	5.190
Social sustainability - Environmental sustainability	0.127*	3.064
Social sustainability - > Supply chain resilience	0.068**	1.774
Economic sustainability - > Supply chain resilience	0.261*	6.404
Environmental sustainability - > Supply chain resilience	−0.130*	−3.879

Indicating significance at *1%, ** at 10%.

4.3 Estimation of model parameters

The created theoretical constructs are now considered to be a linear combination of the observable variables from Table 4. Structural modelling was further applied to estimate the interrelationships between the latent variables presented. The model parameter estimation conducted showed that almost all of the calculated path coefficients of the structural model were statistically significant, with a *p*-value below 0.01, and some below 0.1 (Table 6).

Table 6 shows the parameters of the examined structural model for the selected pathways. All of the cause–effect associations (indicated by arrows) and tested correlation relationships (indicated by lines) were found to be significant. A stronger influence occurs where the path coefficient value is greater. For the analysed constructs, economic sustainability has the strongest impact on supply chain resilience, and with a smaller effect by environmental sustainability. Social sustainability has the least impact on supply chain resilience, only indicating a 10% significance. The analysis of the research results shows unequivocally that there is no correlation between environmental and economic aspects. In addition, the model showed the significance of the correlation relationship between social sustainability and economic sustainability, and also between social sustainability and environmental sustainability—the relationships are shown in the structural model in Figure 1.

4.4 Model evaluation

To evaluate the SEM model, it is suggested that a minimum of four tests of model fit should be satisfied with the acceptability and the compatibility of the model (Kline, 1998; Hair et al., 2021). Table 7 shows the main tests that are used to evaluate the structural

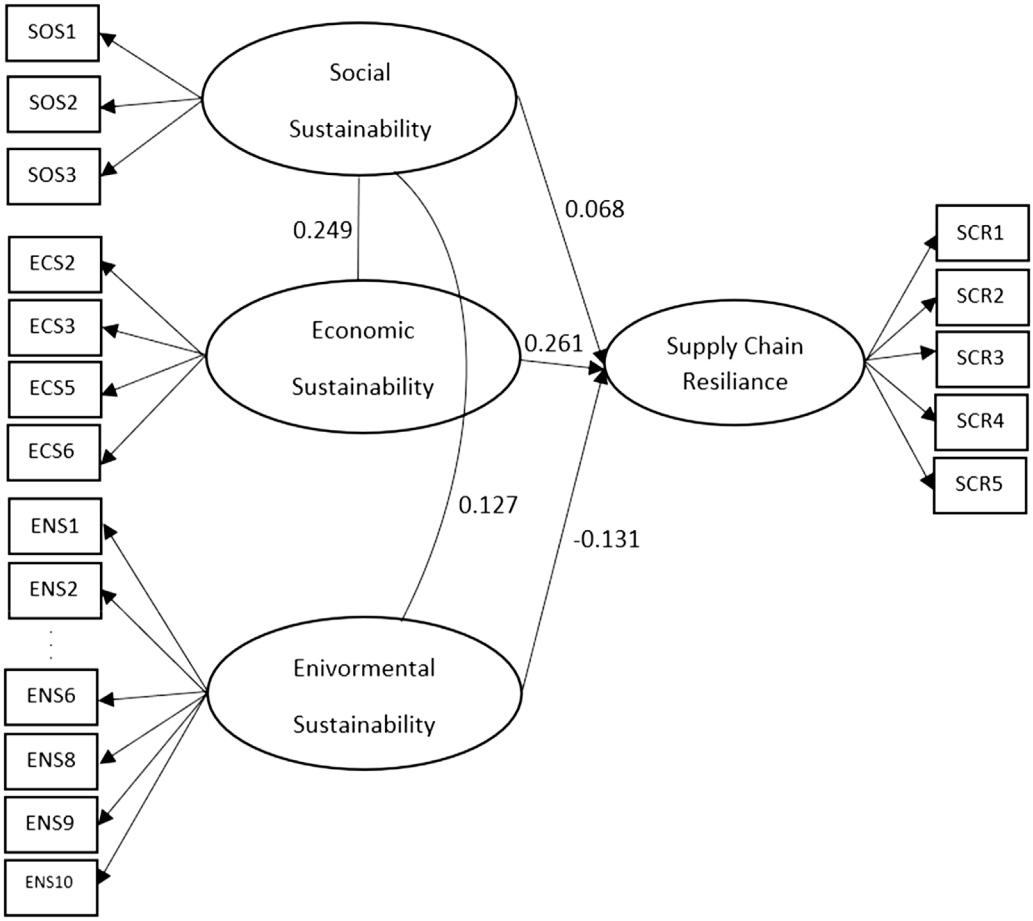

FIGURE 1
The impact of sustainability supply chain on supply chain resilience–SEM model.

TABLE 7 Fit statistics of the measurement model.

Fit index	Value	Acceptable value
χ^2/df	4.79	≤5
Gamma index of the population	0.955	≥0.9
GFI (Goodnes of fit index)	0.927	≥0.9
AGFI (Adjusted goodness of fit index)	0.901	≥0.8
RMSEA (Root mean square of approximation)	0.058	≤0.08
CFI (Comparative fit index)	0.936	≥0.8

equation model: chi-squared, GFI, AGFI, CFI, Gamma index of the population and RMSEA.

The analysed model was correct; the model testing results were sufficiently satisfactory. The ratio of index χ^2 to the number of degrees of freedom was 4.79 (less than 5). The goodness of fit index GFI showed that the model explained 92.7% of the real covariances. On the other hand, the population gamma index was 0.955 and its 90% confidence interval was (0.944, 0.965). These are acceptable measures according to the accepted literature (Segars and Grover, 1993), but the higher the index, the better the measure of fit. Similarly, the root mean square error of approximation (RMSEA) was 0.058—assumed to be below 0.08. Furthermore, the normalized Bentler–Bonett index—a CFI of 0.936, was at an appropriate level (CFI>0.8, Bentler and Bonett, 1980).

5 Discussion

The nature of the disruptions that occur will also have an impact on the continued implementation of sustainability. Challenges such as COVID-19 have not only affected the functionality and the reliability of chains, but also their resilience. Local chains were able to be more resilient in this situation (Thilmany et al., 2021). There is no doubt that further extensive research is needed in the area studied, in order to validate the results already achieved, which in the future, may influence further theoretical development, and above all, will have practical implications and will allow chain managers to build resilient and sustainable supply chains.

Supply chains can increase their resilience using sustainability principles (Negri et al., 2021). This is not the only option; however, in this article, we show that TBL factors have an impact on building resilient and sustainable supply chains. This varies, of course, depending on the relationship, but there is no doubt that research findings have

indicated that sustainability elements have an impact on supply chain resilience. Our research has shown that the economic aspect is the most important, followed by the environmental, and then the social aspect. This relationship and impact is also dependent on the sector and the structure of the companies studied. In our case, farmers constituted the largest research sample, and both the specificity of their activity and the nature of their business indicate that the economic and environmental aspects will play a role in building supply chain resilience using sustainable development principles. This is in accordance with theoretical assumptions, in which, when analysing particular aspects, actions aimed at achieving economic effects are most often indicated as a motivator of the actions performed for sustainable development. This has been confirmed by research, while at the same time constituting a basic element of TBL in building the resilience of supply chains. It also follows logically, from the context of the organizations studied, and in the study of activities by farmers in building resilience, that they both need economic indicators that justify the effectiveness of the actions taken, and as they are one of the most fundamental entities concerning sustainable development, they play the most important roles in these companies.

The economic objectives of sustainable development (Chauhan et al., 2022) are also the easiest to realise and achieve, and so it seems logical that they would continue to be given priority. Environmental aspects, on the other hand, play an increasingly important role. They are placed second in priority, as a result of economic changes and of global trends, and also as a result of the sectors examined. The farmers surveyed ranked this element as second in importance, and this was linked to production itself, with some of the actors offering organic products. Thus, when building their chains and their resilience, they must, in principle, pay attention to the environment.

The issue of social aspect plays a role (Lee Park et al., 2023), but it was ranked the least significant. This was probably due, once again, to the nature of the organisations themselves, as well as their size. The lack of obligation in small- and medium-sized companies, for example, to report on sustainability aspects in full, contributes to this element being treated as the least important. Also, considering the indicator aspects, it has to be pointed out that the parameterization of this area is the least developed, and some elements are not always fully understood by entities such as small- and medium-sized organizations. Nevertheless, the research results clearly indicate that the research questions posed as a result of the identified research gap should be answered in the affirmative. The aspects of sustainability considered in the economic, social and environmental contexts are relevant to the study of supply chain resilience (Zhu and Wu, 2022; Manurung et al., 2023). Each of these elements has an influence, but not to the same extent.

The study presented has several limitations. Firstly, only a few TBL factors were selected for analysis; in future studies, a full catalogue of TBL factors should be created on the basis of a structured literature survey, and they should be divided into universal and industry-specific factors, so that the interrelationships can be easily studied and referred to in terms of the specificity of the industry, or even of the economy. Secondly, the research and analysis of the results were based on studies that had been conducted only in sustainable supply chains in Poland, and in selected industries. Therefore, the results cannot be generalised to other economies. The study and its interpretation may serve as a background for further research; the use of studies from different countries may yield different results, and comparative possibilities will only appear if the coverage is extended. Certainly, research on resilience, especially in an empirical context, must continue to be vigorously pursued (Centobelli, et al., 2020). However, the limitations identified can be turned into assets and elements that contribute to the development of science. There are proposals and demands in scientific publications for research to be conducted in smaller, developing economies (Pagell and Shevchenko, 2014), and in other organisations, as they can be a source of inspiration (and confirmation of theses) (Silva et al., 2021), or they can negate the generalisation of the research and its results from well-developed economies or in strong and global supply chains.

Many studies also indicate that 3BL alone is not sufficient to introduce sustainability into the supply chain (Norman and MacDonald, 2004; Wu et al., 2016; Wu et al., 2018), but it can, however, be helpful in the context of building a resilience system for the supply chain network. Resilience can also be influenced by the structure and the ecosystem of the chain itself, as well as the links and the relationships between these links (e.g., of a regional nature) (Silva et al., 2021). In the context of examining the sustainability as well as the resilience of the chain, the grouping of different levels of the chain may also be considered (Mehrjerdi and Shafiee, 2021), including different links (manufacturers, distributors, suppliers or retailers), as each link may have a different approach to the indicated strategy, and different implementation conditions.

6 Conclusion

Many studies indicate that the dominant factors in sustainable supply chain development are social and economic factors. Social development can become a determinant of economic and environmental benefits while reducing the operational risks (Tseng et al., 2019). The authors filled the research gap by answering the research questions. The authors' approach is the authors' contribution to the research on the resilience of chains using the principles of sustainable development; the theses and questions posed on the basis of the literature on the subject have been empirically verified, and the structural research methodology used has justified the validity of the theses posed and the novelty of the research. The results of the research justify that the elements of sustainable development have an impact on the resilience of supply chains.

Despite the research into risk management being motivated by natural and man-made disasters, the pandemic further highlighted the need to consider resilience from the perspective of an intertwined supply network (Ivanov and Dolgui, 2020; Queiroz et al., 2020). In the context of supply chain management, a supply network systems perspective is necessary when designing inclusive governance processes and mechanisms that are key to establishing resilient operations in post-crisis periods (Khurana et al., 2021). This article extends our current knowledge on the use of 3BL aspects in building the resilience of sustainable supply chains; furthermore, from the research results, it shows that supply chain sustainability resilience research must consider the influence of sustainability factors. In the context of sustainable development, its elements create mechanisms to support the construction of such a chain preserving and applying the principles of sustainable development, thus building its resilience. It also has managerial implications, indicating which sustainability factors have so far been paid attention to in the practices of the companies studied. From a theoretical point of view, it shows that there are yet other factors that can or should be considered. By

following the proposed catalogue, and by knowing their impact, managers can promote an effective strategic orientation for building resilience in a sustainable supply chain. Using the concept of sustainability, and at the same time, seeking to strengthen resilience effects on chain operations, it therefore seems necessary to apply new paradigms to assess the actions that are taken.

Data availability statement

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the participants was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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