Analyzing Quantity-based Strategies for Supply Chain Sustainability and Resilience in Uncertain Environment

Dounia SAIDI[1], Aziz AIT BASSOU[2], Mustapha HLYAL[3], Jamila EL ALAMI[4]
LASTIMI Laboratory, High School of Technology in Sale, Mohammed V University in Rabat , Rabat, Morocco[1, 2, 4]
Center of Excellence in Logistics, Higher School of Textile and Clothing Industries, Casablanca, Morocco[3]

***Abstract*—In today's interconnected world, where supply chains are the backbone of commerce, ensuring their resilience and sustainability is paramount. This study investigates how quantity-based strategies in supply chain networks are influenced by sustainability and resilience considerations. A conceptual framework is devised, focusing on a two-echelon supply chain network comprising a central supplier and multiple stores. A stochastic mathematical model is constructed to tackle demand uncertainty while incorporating parameters related to sustainability and resilience. Competitive negotiations between suppliers and stores aim at maximizing expected profits. Two store configurations are examined: non-cooperative and cooperative. Supplier resilience is reinforced through strategies like security stocks and diversified sourcing, while sustainability efforts are considered by the supplier and stores. Results show that demand following a uniform distribution benefits stores and suppliers, and cooperative behavior among stores leads to higher profitability. Sustainability initiatives impact expected profits, with security stocks particularly advantageous for supplier profitability. The utilization of foreign products has a detrimental effect on expected profits, emphasizing the significance of government regulation via customs fees. The study underscores the importance of integrating sustainability and resilience in supply chain networks. It concludes with reflections on model limitations and proposes avenues for future research in this domain.**

Keywords—Supply chain management; competition; sustainability; resilience; demand uncertainty

I. Introduction

In today's business world, managing supply chains is crucial for global expansion, but it faces challenges in sustainability because of growing environmental worries. The delicate balance between profit-driven objectives and eco-friendly practices is underscored by intense competition and demand uncertainties in the global market [1], [2]. This complex interaction means that companies need to be flexible and have good planning for long-term success. Managing uncertainty is very important, not just for making supply chains more sustainable and resilient, but also for staying competitive [3]. Within the supply chain network, the competition between a supplier and a store, often centered around quantity negotiation [4], This underscores the complex scenario that necessitates meticulous equilibrium to address the requirements of all stakeholders.

This research conducts a thorough investigation into sustainability and resilience within a supply chain, comprising a single supplier and multiple stores. It examines challenges related to managing demand uncertainty and profitability, and explores how sustainability impacts the supply chain's ability to handle disruptions, aiming to enhance both sustainability and resilience [5], [6]. Additionally, it seeks to uncover strategies for stores to maximize profits while maintaining sustainable practices, including quantity-based policies, operational efficiency, and the integration of sustainable approaches for profitability [4]. The study concludes by advocating for support of domestic products, exploring methods to promote local manufacturers, manage demand uncertainties, and encourage collaboration among supply chain stakeholders, particularly among stores. This collaboration presents an opportunity to pool resources and reduce costs, aligning with sustainability and resilience objectives.

Numerous comparable studies have investigated the sustainability and resilience of supply chains [7], [8], [9], [10], notably, a prior study [10] where a deterministic model was introduced. It analyzed the strategies of suppliers and stores to maximize profit while achieving sustainability and resilience objectives. However, the study did not account for managing uncertainty, a crucial factor in accurately reflecting real-world complexities. The challenge of the uncertain demand, is amplified by the potential conflict between implementing sustainability and resilience measures and the economic interests of supply chain actors.

Therefore, this study addresses a gap in the literature by investigating the interconnected issues of sustainability, resilience, and managing demand uncertainty within a supply chain [11], [12]. The significance of this research lies in several key aspects. Firstly, it underscores the importance of managing demand uncertainty as a critical approach to enhancing resilience, avoiding overstocks, and preventing shortages [13]. Secondly, the paper uniquely examines sustainability and resilience as competitive advantages, consistently advocating for domestic production [7], [8], [9], [10]. Additionally, cooperation can serve as a competitive advantage for certain companies, offering opportunities to reduce costs through resource pooling, shared logistics, and joint strategies, as seen in the case of stores. Given the complex nature of these interactions, the current study seeks to investigate the following research questions.

- How can the store and the supplier comply with sustainability and resilience requirements and still be competitive?
- What are the quantity-based strategies that the stores and the supplier can employ to maximize their expected profits while taking into account sustainability and resilience?
- What configuration is more advantageous for the store to maximize its profit while also meeting sustainability requirements?

To address these research questions, we will expand on the research conducted in study [10], indeed, this research work focuses on a monopolistic, sustainable, and resilient model operating under uncertainty with two-echelons: the supplier and multiple stores. These entities engage in negotiations to maximize expected profits, leading to two scenarios. The first scenario involves non-cooperation, where individual stores and the supplier independently strive to maximize expected profits based on the delivery quantity. In the second, cooperative scenario, stores collaborate to jointly optimize expected profits while mitigating stockout risks, utilizing a central warehouse for return logistics of excess quantities. Various actors in the supply chain, such as the central supplier, stores, and the government, implement specific strategies. The model addresses resilience by managing demand uncertainty through a stochastic model, implementing security stocks dedicated to each store, and diversifying product sources. Sustainability is incorporated through unit costs associated with eco-friendly practices. Cooperation introduces a central warehouse as a backup supplier, enhancing overall resilience. Logistics of returns are managed to reduce waste and product depreciation [14], [15] amid uncertain demand. The depreciation cost, covering product returns and replenishment fees, aims to promote responsible inventory management and minimize unwarranted returns [14], [15].

The paper is structured as follows: Section II explores previous studies about quantity-based strategies in supply chains. It focuses on making supply chains more sustainable and resilient in competitive environments and uncertain situations. Section III concentrates on building and analyzing a model that includes two different quantity-based strategies. The first strategy involves the non-cooperation of stores, competing independently with the supplier. The second strategy involves a cooperative scenario where stores work together to maximize their expected profit, managing the competitive dynamics with the supplier. In Section IV, a numerical analysis is conducted, employing examples to substantiate the selection of quantity-based strategies in each scenario and making comparisons between uniform and normal distribution cases. Moving to Section V, we present and thoroughly analyze the outcomes obtained from both the developed model and the numerical analysis. Section VI concludes by presenting final observations, highlighting limitations, and suggesting potential avenues for future research.

II. Literature Review

Academic research investigates how uncertainty, resilience, and sustainability meet in competitive supply chains, aiming to guide companies in maintaining efficiency and ecological responsibility despite disruptions. This review emphasizes studies aligning with sustainable strategies under uncertainty and employing game theory to understand competition dynamics.

A. Supply Chain in Competition and Under Uncertainty

Nowadays, strategies to adopt in supply chains to be competitive become significant under conditions of uncertainty, as they play a pivotal role in navigating dynamic market fluctuations and mitigating risks. Broadly, there are two categories of uncertainties: operational and disasters [13]. Operational uncertainties pertain to the configuration of activities, encompassing factors like order timing and product prices [16]. The literature shows that various studies focus on disruption risks in supply chain systems through risk mitigation strategies, and aimed at identifying suitable measures throughout different stages, pre-disaster, during-disaster, and post-disaster [17], [18]. On the other hand, other studies focused on risk aversion strategy, where disruption represents a tangible and unplanned form of uncertainty that necessitates certain actions to anticipate and control uncertainty. In this context, scenario-based models prove to be valuable tools for incorporating disruption and uncertainty in both parameters and variables [19]. A scenario-based approach provides flexibility in addressing uncertainty by considering optimistic, pessimistic, and realistic scenarios [19], [20], [21].

On a different note, it is imperative to emphasize the critical significance of crafting a robust optimization model that not only acknowledges but adeptly addresses the inherent uncertainties linked to parameters and decision variables [22]. The principal origins of such uncertainty, stemming from randomness and fuzziness, have been extensively recognized and documented in notable research works [23], [24]. This profound comprehension of uncertainties is pivotal as it forms the basis for implementing robust scenario-based approaches. The authors in their study [25], consider the investments made by remanufacturers in corporate social responsibility initiatives. Numerous studies within this domain seamlessly integrate the pervasive element of uncertainty. Utilizing stochastic and dynamic programming is by to harmonize sustainability and uncertainty [26]. A bi-objective model is crafted, balancing sustainability with economic costs while addressing uncertainties and demand fluctuations. This study focuses on optimizing the management of unused medications in the pharmaceutical supply chain. Exploring decentralized and centralized models, it introduces an innovative shortage risk-sharing purchase contract. Numerical analysis confirms its effectiveness in aligning the supply chain, improving profitability, and ensuring financial sustainability. This model provides a strategic approach to minimize costs while highlighting the advantages of various management approaches in the pharmaceutical sector.

B. Sustainability Under Uncertainty

In the evolving landscape of supply chain management, the integration of sustainability has become imperative. Organizations are increasingly recognizing the need to align operations with environmental considerations, societal expectations, and effective management of uncertainty [27]. The strategic deployment of strategies is pivotal in balancing economic objectives with sustainability goals [10]. This symbiotic relationship holds the key to resilience and long-term success in the global marketplace.

Navigating the intricate landscape of supply chains, the integration of sustainability becomes inherently linked with the overarching concept of uncertainty as organizations grapple with dynamic variables and unforeseen challenges in their pursuit of environmentally and socially responsible practices [13]. Many studies address challenges of uncertainty in designing a sustainable and competitive supply chain. Incorporating environmental, societal, and economic dimensions. The model proposed of the study [28] concerns a supply chain structure involving two clusters, a retailer, and a government orchestrator. The application of six model variations to a real-world case study in the Iranian leather industry illustrates the model's utility in navigating uncertainties while promoting sustainability across the supply chain. Managing production, distribution, and staffing while dealing with uncertainty in the perishable goods industry is the concern of the work [29] that used a new method, FDSL-NSGA-II. Tested in the dairy industry, this model improves the balance between various aspects of the supply chain and reduces environmental impacts. Similarly, an interesting work presented a sustainable dual-objective blood supply chain [30] , highlighting diverse environmental and social considerations in the blood decomposition process. They integrated uncertainty into the model, specifically addressing variables such as the volume of blood collected at transfusion laboratories and the decomposition rate at blood decomposition facilities. Delving into the intricacies of supply chain management and decision making strategies, an investigation conducted by [31] incorporates considerations of carbon emissions and customer preferences, all within the context of supply uncertainties stemming from the ongoing impact of COVID-19. Utilizing a non-linear programming model, the study formulates optimal strategies, shedding light on the potential risks of substantial losses and the consequential impact on business sustainability when uncertainties are not adequately addressed.

C. Sustainable Supply Chain in Competition and Under Uncertainty

Numerous studies have been undertaken to address the effective handling of disruptive risks [11], [18], [32]. They have focused on implementing supply chain resilience, utilizing both preventive and reactive strategies, and sustaining accomplishments in risk management within the supply chain over an extended period. Studies like [33], [34] focused on reactive strategy. Such as the examination a pharmaceutical supply chain network design problem, incorporating considerations for resilience and sustainability in the face of operational and disruptive risks [33]. Also, the investigation of both resilience and sustainability concurrently within the context of Supply Chain Network Design in the presence of disruptive and operational risks [34]. As a preventive strategy, the work of [35] focused on enhancing resilience against disruptive risks and developed an environmentally sustainable supply chain network. On the other hand, some other proactive strategies were adopted to enhance profitability during disruptions [11]. The simultaneous management of disruption risks and uncertainties was revealed to contribute significantly to achieving sustainability goals while reducing associated costs. Regarding the aim to design a resilient supply chain within a competitive environment, the focus on redesigning a resilient topology for a specific setting to quickly recover from disruptive incidents was examined in the work [36] proposing three proposed policies, maintaining emergency stock at retailers, reserving backup capacity at suppliers, and employing multiple-sourcing, are explored to mitigate disruption risk. Simultaneously, another study delves into the realm of intra-supply chain competition, where producers and resellers navigate uncertainties and disruption risks to achieve their respective goals [37]. Sustainability and resilience both play crucial roles in shaping supply chain pricing strategies. Additionally, the investigation into the promotion of domestic products was explored in the study [10] and adopted a preventive strategy for risk aversion. The proposed model delves into stakeholder interactions, revealing the substantial impact of stores' sustainability efforts on pricing, supplier resilience strategies, and the role of governmental regulations. However, the study acknowledges limitations in the deterministic model, citing its potential oversimplification of real-world complexities and emphasizes the importance of managing demand uncertainty through a stochastic model.

Maximizing profit forms a central focus in a significant portion of sustainable resilient supply chain [38]. Exploring the complexities of the location-pricing problem in a two-echelon supply chain, this study underscores the dual focus on profit maximization and effective uncertainty management. Notably, considering social preferences, especially in a competitive context, leads to increased profit margins for the entire supply chain [12]. Furthermore, the exploration extends to scenarios where the collection process is collaboratively undertaken by both the manufacturer and the retailer, as observed in the study by [39], which specifically delves into decision-making process within a cross-channel recycling context. Consumer consciousness is at the forefront when scrutinizing two distinct strategies: one employing uniform prices for both new and remanufactured products, and the other adopting disparate pricing [40]. The findings reveal potential advantages in equal pricing, especially when a significant proportion of consumers prioritize environmental considerations. In such instances, aligning strategies with the preferences of environmentally conscious customers can yield favorable outcomes.

Many authors explored centralized and decentralized models in context of competition. The optimization of the management of unused medications in the pharmaceutical supply chain was investigated [41]. The model introduced an innovative shortage risk-sharing purchase contract. Numerical analysis confirms its effectiveness in aligning the supply chain, improving profitability, and ensuring financial sustainability. Similarly, another research work explored the imperative for green reform amid environmental challenges. Investigating Green Technology Investment (GTI) decisions, it unveils a two-sided matching mechanism's influence on stable matches [42]. The findings highlight nuanced impacts of carbon prices and green improvement coefficients on GTI, product pricing, and profits. Similarly, the centralized and decentralized scenarios were Distinguished in the work [43] where quality considerations were incorporated into the analysis.

With the intention of closing a gap in the literature, we consider uncertainty, sustainability and resilience parameters within a supply chain while model. As in practice, stochastic parameters play a pivotal role in decision-making processes, and integrating sustainability factors ensures a comprehensive approach that aligns with contemporary environmental and ethical considerations. This inclusive model aims to provide a more accurate representation of real-world scenarios, contributing to a nuanced understanding of the interplay between uncertainty, sustainability, and quantity-based strategies in supply chain management.

III. Modeling Formulation and Analysis

In this section, the focus is on the development and analysis of a supply chain network model under competitive dynamics, incorporating uncertainty parameters. The exploration encompasses the mathematical representation of variables such as quantity, sustainability, and resilience.

A. Model Description and Assumptions

In this study, a two-echelon supply chain model is developed, as illustrated in Fig. 1 and Fig. 2, featuring a supplier, stores. The model addresses uncertain demand through a stochastic demand (D_i . Effectively managing uncertainty in demand is pivotal for the supply chain's operational efficiency and resilience. By including stochastic elements, the model recognizes variability of the market demand, helping the supply chain make decisions in various situations.

In the developed model, the supplier and the store, both in competition, seek to maximize expected profits, initiating a negotiation where each determines the optimal delivery quantity. This leads to two scenarios: the non-cooperative scenario, where store i and the supplier compete to individually maximize their expected profits by adopting a strategy based on the quantity to deliver(Q_i). In contrast, the cooperative scenario involves collaboration among stores to jointly maximize their expected profits while mitigating the risk of stockouts. This collaboration is facilitated by utilizing a central warehouse to manage the logistics of returns for excess quantities from store i.

Each actor of the supply chain influences others through specific strategies. The central supplier distributes a quantity (Q_i) of both foreign and domestic products to multiple stores at a wholesale price(ω_i). As the ultimate points of sale, stores not only retail products in the market at a designated price (p_i) but also play a pivotal role in making critical decisions related to delivery quantities (Q_i), sustainability initiatives (e_i), and managing uncertainties in demand [44]. The supplier, while not directly involved in production, assumes a pivotal role in distribution, negotiating quantities (Q_i), and managing security stock (ψ_i) with each store for more resiliency [45] and considering sustainability (e_s) for each product. The government intervenes by imposing custom fees (τ) on foreign products and providing subsidies (ν) to boost domestic products [9]. Additionally, it fulfills a regulatory function by balancing the quantities of foreign and domestic products in the market, diversifying product sources for enhanced resilience, and promoting sustainability practices.

The resilience of the supply chain is comprehensively addressed in this model, manifesting in multiple ways. Firstly, managing demand uncertainty (D_i) through a stochastic model is a crucial element to mitigate the risks of disruptions and ensure a high level of customer service [44]. Secondly, the implementation of security stocks (ψ_i) dedicated to each store i by the supplier further strengthens resilience in response to the specific demand of store i . This reserved quantity (ψ_i)serves as a buffer, enabling the supplier to adeptly address fluctuations in demand and unexpected disruptions within the supply chain [45]. Thirdly, the diversification of product sources affords the option between locally sourced and imported products, offering an import alternative in the event of a shortage of local products [44]. Additionally, in the cooperative scenario, the introduction of a central warehouse in the initial configuration allows for consolidating surplus products from each store through mutualization, thereby ensuring supply in times of need. This central warehouse serves as a backup supplier [44] for the store, constituting a second source of products and contributing to fortifying its resilience.

Sustainability in the supply chain is considered by both the supplier and the store. The costs (e_s), (e_i) and (e') are all of them sustainability unit costs for the supplier, the store and the central warehouse respectively. These costs include expenses of activities and investments that promote sustainability, such as addressing the CO_2 emissions tax [46] linked to product transportation, refurbishing products in an environmentally friendly manner, mandating sustainable packaging, implementing recycling initiatives, etc. As demand is uncertain, the potential risk of surplus products $(Q_i - D_i)$ in each store becomes a concern [47]. Therefore, managing the logistics of returns for excess quantities in the cooperative case is a crucial element, thus reducing waste and product depreciation (l).

The depreciation cost (l) considered between the supplier and stores, represents the expense linked to product returns from stores to the supplier [14], [15]. This cost is designed to offset the loss in value resulting from product use in the store, aiming to incentivize responsible inventory management and minimize unwarranted returns. The depreciation cost also encompasses replenishment fees, covering the expenses associated with reintegrating returned products into the supplier's inventory. These expenses typically involve processes such as inspection, refurbishment, and repackaging.

1) Non-cooperative scenario: In the non-cooperative model as illustrated in Fig. 1, stores and the supplier, all in competition, seek to maximize their expected profits independently. Individual stores engage in negotiations with the supplier, independently determining the optimal quantity

(Q_i^{*NC}) of products to order considering demand uncertainty. On the other hand, the supplier aims to maximize sales and determine its optimal quantity ($\widehat{Q_i}^*$) of products to deliver to the store.

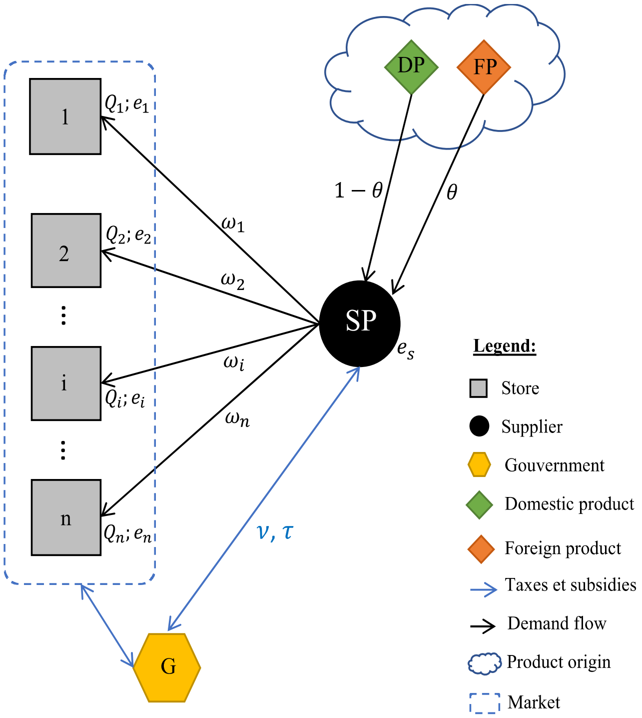

Fig. 1. The non-cooperative supply chain network model comprising stores and a single supplier.

The potential risk of surplus products $(Q_i - D_i)$ in each store is a concern when $(D_i > Q_i)$. Therefore, a depreciation cost $(l)$is considered in the non-cooperative configuration for the store [14], [15]. Similarly, the shortage cost (z) is mandatory if case of stockouts [4]. For the store, this represents an expense; however, it enables the supplier to not only mitigate financial losses associated with returns but also encourages stores to maintain a high standard of quality in their inventory management practices.

2) Cooperative scenario: In the non-cooperative configuration, stores engaged in individual competition with the supplier strive to maximize their expected profits independently. This model, characterized by a lack of cooperation, does not foster synergy among stores, which could potentially lead to a reduction in costs related to storage and depreciation. Furthermore, the presence of excess quantities introduces an increased risk of expiration or obsolescence, resulting in financial losses for the stores.

On the other hand, in the cooperative configuration illustrated in Fig. 2, stores are encouraged to collaborate to maximize their expected profits while still competing with the supplier and engage in negotiations determining the optimal quantity (Q_i^{*CO}). This collaboration materializes through the establishment of a central warehouse, playing a crucial role, especially in the face of uncertain demand. Excess quantities $(Q_i - D_i)$ that remain unsold in the stores are redirected to this central warehouse, acting as a reserve to prevent stockouts in case of high demand $(D_i > Q_i)$. This cooperation among stores enables the distribution of responsibilities among them and the pooling of resources by sharing fixed costs of the central warehouse represented by the ratio (φ) that is the quote part of central warehouse fixed costs for each store, minimizing costs, notably the depreciation cost (l) and shortage cost (z) that are not considered in the cooperative scenario for the store, and reinforcing the resilience of the stores. This centralization also minimizes the risk of expiration, depreciation, or obsolescence of products in the stores, providing the opportunity to sell them in other secondary markets, notably to the supplier.

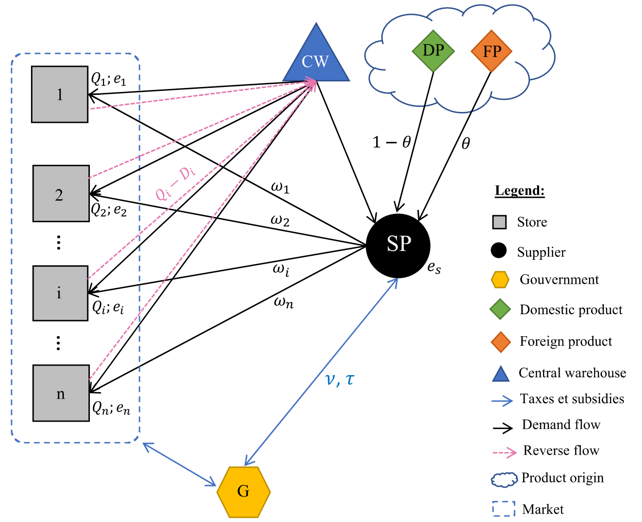

Fig. 2. The cooperative supply chain network model comprising stores and a single supplier.

The main objective of this competitive supply chain model of a single supplier and multiple stores, is to explore the interactions among these actors, their impact on each other, and the influence of sustainability and resilience on their expected profits.

3) Assumptions: In the two scenarios outlined in our uncertain supply chain model, various fundamental assumptions are formulated to simplify and delineate the context of our analysis. These assumptions establish the parameters, relationships, and foundational conditions that govern our system. They play a crucial role in framing our study with precision and rigor.

- $l < \omega_i, p_i$
- We assume a market configuration characterized by monopoly at store level;
- We assume that the customers have the same quality preference for products;
- We assume that all products are depreciated at the same level;
- Store i receives its supplies from a single supplier;
- In the cooperative configuration, store i can be supplied by the central warehouse;

- The supplier sets varying selling prices through negotiations with each store i;
- The Store i handles the collection and transportation of unsold surplus products to the central warehouse, incurring CO_2 emissions that are subject to taxation by the government (e');
- The supplier dedicates an inventory quantity (ψ_i) as a security stock for each store i.

Given the aforementioned assumptions, the expected objective functions of the problem for both scenarios, the cooperative and non-cooperative, to be modeled are as follows:

- Maximize store expected profit (cooperative and non-cooperative scenario);
- Maximize supplier expected profit.

4) Model parameters and variables: The notations employed in the mathematical model are listed below. The superscripts 'NC' and 'CO' signify the non-cooperative and cooperative scenarios, respectively.

Parameters and variables

D_i: The stochastic demand at the store, which adheres to the probability density function $f(x)$ and the cumulative distribution function $F(x)$
Q_i : order quantity of store i
p_i : unit price of a product at store i
p' : buyback unit price of a product by the central warehouse from the store i
e_i: unit sustainability cost for store i
e_s: unit sustainability cost for the supplier
e': unit sustainability cost for the central warehouse
c_i : store's operating unit cost
c_s: supplier's operating unit cost
c : overall operating unit cost of supplier
z : shortage cost per unit for store i
ψ_i : ratio of inventory quantity reserved for store i
δ: ratio of supplier's wholesale price dedicated to holding products
l : depreciated cost
τ : custom fees
ν : government subsidy
θ : ratio of quantity of foreign products, $\theta \epsilon [0,1]$
φ: quote part of central warehouse fixed costs for each store
ω_i : supplier wholesale price of the product
ω': central warehouse wholesale price of the product

Expected profit functions

$E^{NC}(\pi_i)$: expected profit of store i for the non-cooperative scenario
$E^{CO}(\pi_i)$: expected profit of store i for the cooperative scenario
$E(\pi_{i,s})$: expected supplier profit with one store
$E(\pi_s)$: expected supplier profit for the whole network

B. Model Construction and Analysis

The mathematical model presented in this research provides a formal representation of key interactions within a network involving a central supplier and multiple stores. It offers an analytical framework to explore and interpret underlying dynamics within the contexts of two scenarios: cooperative and non-cooperative one.

5) Expected profit of Store i

a) Expected profit of Store i for the non-cooperative scenario

In this sub-section, the store's profitability is studied for the non-cooperative structure.

The expected profit Eq. (1) for store i for the non-cooperative configuration is given as follows.

$$E(\pi_i^{NC}(Q_i)) = (p_i - e_i)E[min(Q_i, D_i)] - (\omega_i + c_i)Q_i - zE[max\,(0, D_i - Q_i)] + (\omega_i - l)E[max\,(0, Q_i - D_i)] \quad (1)$$

In the Eq. (1), the first term represents the total revenue generated by selling products in the market (p_i), taking into account the sustainability cost of the store i (e_i) that varies due to demand uncertainty. The second term expresses the cost of purchasing products from the supplier (ω_i) , minus the operational cost (c_i) of store i. The third term indicate the shortage cost (z) per unit for store i. the last term represent difference between the supplier wholesale price and the depreciation cost (l) in the case of the surplus of quantity of items. The purpose of this cost (l) is to counterbalance the reduction in value attributed to product use in the store, with the goal of encouraging responsible inventory management.

With some algebra, the expected profit for store i in the non-cooperative scenario will be the following Eq. (2).

$$E(\pi_i^{NC}(Q_i)) = -Q_i(c_i + l) + E(D_i)(l - e_i + p_i - \omega_i) - (l - e_i + p_i - \omega_i - z)\int_{-\infty}^{Q_i}(D_i - Q_i)f(D_i)dD_i \quad (2)$$

The store i can adopt the strategic option of determining the optimal quantity to order from the supplier considering sustainability. If we consider the scenario where the store exclusively prioritizes the quantity strategy, the optimal quantity for maximizing expected profit based on the Eq. (2) is presented in the Eq. (3):

$$Q_i^{*NC} = F_{D_i}^{-1}\left(\frac{-c_i - l}{l - e_i + p_i - \omega_i - z}\right) \quad (3)$$

Proof. Maximum expected profit is sought by deriving the expected profit function $E(\pi_i^{NC}(Q_i))$.

$$\frac{\partial \mathrm{E}(\pi_i^{NC}(Q_i))}{\partial Q_i} = (-c_i - l) - (l - e_i + p_i - \omega_i - z)F_{D_i}(Q_i)$$

The second derivative of the expected profit function for the store i with respect to (Q_i) is: $\frac{\partial^2 \mathrm{E}(\pi_i^{NC}(Q_i))}{\partial^2 Q_i} = -(l - e_i + p_i - \omega_i - z)f_{D_i}(Q_i)$

We have: $\frac{\partial^2 \mathrm{E}(\pi_i^{NC}(Q_i))}{\partial^2 Q_i} < 0$ thus, the function admits a maximum.

Knowing that $F_{D_i}(Q_i) = \int_{-\infty}^{Q_i} f(D_i)dD_i$ so $f_{D_i} > 0$

And $(l - e_i + p_i - \omega_i - z) > 0$ with $p_i > e_i + \omega_i + z$ and $l, e_i, p_i, \omega_i, z > 0$

The maximum is obtained by solving $\frac{\partial \mathrm{E}(\pi_i^{NC}(Q_i))}{\partial Q_i} = 0$.

b) Expected Profit of Store i for the Cooperative Scenario

In this sub-section, the store's profitability is examined within the cooperative configuration, where stores cooperate to maximize their expected profits while still competing with the supplier.

The expected profit Eq. (4) for store i in the cooperative scenario is given as follows.

$$E(\pi_i^{CO}(Q_i)) = (p_i - e_i)E[min \ \ (Q_i, D_i)] - (\omega_i + c_i)Q_i - \omega' E[max \ \ (0, D_i - Q_i)] + (p' - e')E[max \ \ (0, Q_i - D_i) + \varphi] \quad (4)$$

In the Eq. (4), the initial term signifies the overall revenue derived from selling products in the market at the store i's price (p_i), considering the store's sustainability cost (e_i). Second term denotes the expense incurred in procuring products from the supplier (ω_i), minus the operational cost (c_i) of store i. The third term indicates the replenishment quantity $(D_i - Q_i)$ required and supplied by the central warehouse and (ω') is the central warehouse wholesale price of the product. The fourth term represents the store's revenue obtained by reselling the surplus quantity $(Q_i - D_i)$ to the central warehouse at the price (p') considering the central warehouse sustainability cost (e_i) which is proportionally borne by each store i. The last term (φ) represents the quote part of each store i of central warehouse expenses.

With some algebra, the expected profit for store i in the cooperative scenario will be the following Eq. (5).

$$E(\pi_i^{CO}(Q_i)) = (p' - e')\varphi + \ Q_i(-e' + p' - \omega_i - c_i) + E(D_i)(e' - e_i + p_i - p') + (-e' + p' - \omega' + e_i - p_i)\int_{-\infty}^{Q_i}(D_i - Q_i)fD_i dD_i \quad (5)$$

By adopting a strategy based on quantity, the optimal quantity for the store i to order from the supplier considering sustainability is the following presented in the Eq. (6):

$$Q_i^{*CO} = \ F_{D_i}^{\ -1}\left(\frac{-e' + p' - \omega_i - c_i}{-e' + p' - \omega' + e_i - p_i}\right) \quad (6)$$

Proof. Maximum expected profit is sought by deriving the profit function $E(\pi_i^{NC}(Q_i))$.

$$\frac{\partial \mathrm{E}(\pi_i^{CO}(Q_i))}{\partial Q_i} = (-e' + p' - \omega_i - c_i) + (-e' + p' - \omega' + e_i - p_i)F_{\mathrm{D}_i}(Q_i)$$

The second derivative of the expected profit function for the store i with respect to $(Q_i)$is: $\frac{\partial^2 \mathrm{E}(\pi_i^{CO}(Q_i))}{\partial^2 Q_i} = -(-p' + p_i + \omega' - e_i + e')f_{\mathrm{D}_i}$

We have: $\frac{\partial^2 \mathrm{E}(\pi_i^{CO}(Q_i))}{\partial^2 Q_i} < 0$ thus, the function admits a maximum.

6) Expected profit of supplier: In the context of both non-cooperative and cooperative configurations, the supplier seeks to maximize its expected profit with regard to individual stores and the entire network. In this subsection, we begin by examining the supplier's profitability concerning store i and subsequently explore the overall network profitability.

a) Expected profit of supplier in relation to one store i

Our attention is directed towards analyzing the supplier's profitability with regard to one store i.

We consider the overall operating unit cost of supplier $c = c_s + e_s$ with (e_s) and (c_s) as sustainability cost and the operational cost of the supplier respectively.

The supplier expected profit function related to one store i is as follows:

$$E\left(\pi_{i,s}(Q_i)\right) = Q_i(\omega_i - c) - (\omega_i - l)E[max(0, Q_i - D_i)] - \delta\omega_i\psi_i Q_i \quad (7)$$

In the Eq. (7), the first term pertains to the supplier's expected profit from selling the quantity (Q_i) to a single store i at the price (ω_i), while accounting for sustainability costs (e_s) which mainly concern the CO_2 emissions tax linked to product transportation and operational expenses (c_s). The second term involves the cost of unsold quantities $(Q_i - D_i)$ that have depreciated (l). The final term is the holding cost $(\delta\omega_i)$ associated with the reserved quantity $(\psi_i Q_i)$ allocated by the supplier to store i. Here, (δ) and (ψ_i) represent the ratio of supplier's wholesale price dedicated to holding products and ratio of inventory quantity reserved for store i respectively.

With some algebra, the expected profit for the supplier will be the following Eq. (8):

$$E(\pi_{i,s}(Q_i)) = E(D_i)(-l + \omega_i) - Q_i(c_s + e_s - l + \delta\psi_i\omega_i) - (-l + \omega_i)\int_{-\infty}^{Q_i}(D_i - Q_i)f(D_i)dD_i \quad (8)$$

Considering the strategy where the supplier exclusively prioritizes the quantity, the optimal quantity for maximizing its expected profit with one store i based on Eq. (8) is presented in the Eq. (9):

$$\widehat{Q}_i^{\ *} = F_{D_i}^{\ -1}\left(-\frac{(c_s + e_s - l + \delta\psi_i\omega_i)}{(\omega_i - l)}\right) \quad (9)$$

Proof. Maximum supplier expected profit is sought by deriving the expected profit function $E(\pi_{i,s}(Q_i))$.

$$\frac{\partial E(\pi_{i,s}(Q_i))}{\partial Q_i} = -(c_s + e_s - l + \delta\psi_i\omega_i) - (\omega_i - l)F_{D_i}(Q_i)$$

The second derivative of the expected profit function for the supplier with respect to $(Q_i)$is:

$$\frac{\partial^2 \mathrm{E}(\pi_{i,s}(Q_i))}{\partial^2 Q_i} = -(\omega_i - l)f_{D_i}(Q_i)$$

We have: $\frac{\partial^2 \mathrm{E}(\pi_{i,s}(Q_i))}{\partial^2 Q_i} < 0$ thus, the function admits a maximum. Since the wholesale price (ω_i) of the supplier is significantly higher than the depreciation cost (l), the density function f_{D_i} is positive.

The maximum is obtained by solving $\frac{\partial E(\pi_{i,s}(Q_i))}{\partial Q_i} = 0$.

b) Expected profit of supplier for the whole stores network

In this subsection, our analysis is initiated by the examination of the supplier's overall expected profitability throughout the entire network, incorporating elements extending beyond direct dependence on store demands. These elements include the promotion of domestic products through subsidies and the taxation of foreign products, presenting an alternative option regulated by the government.

The supplier expected profit function for the whole network is presented in the Eq. (10):

$$E(\pi_s(Q_i)) = \sum_{i=1}^{n} E(\pi_{i,s}(Q_i)) - C(\tau) + I(\nu) \quad (10)$$

With:

$$\sum_{i=1}^{n} Q_i = Q, C(\tau) = \tau.\theta Q, I(\nu) = (1-\theta)\nu Q$$

The customs fees paid by the supplier to the government for the percentage (θ) of the quantities imported are represented by $C(\tau)$. Contrariwise, the government grants the supplier a subsidy, $I(\nu)$, for a percentage $(1-\theta)$ of the quantities obtained from local suppliers.

Considering w mean wholesale price of the supplier, then:

$$w = \frac{\sum_{i=1}^{n} \omega_i}{n}$$

To make the calculation easier, we assume that $\sum_{i=1}^{n} \omega_i Q_i = nwQ$ and that the stores order almost the same quantities. The overall expected profit of the supplier is the sum of the expected profits made with each store i and is represented in the Eq. (11):

$$\sum_{i=1}^{n} E(\pi_{i,s}(Q_i)) = nE(D_i)(-l+w) - Q\,(c_s + e_s - l - \delta\psi_i nw) + \mathrm{n}(l-w)\int_{-\infty}^{Q_i} F_{D_i}(Q_i) \quad (11)$$

By replacing Eq. (11) in Eq. (10) we get the global supplier expected profit in the Eq. (12):

$$E(\pi_s(Q)) = n\Big[Q(\nu - \theta(\nu+\tau) - c_s - e_s + l + \delta\psi_i nw) + E(D_i)(-l+w) + (l-w)\int_{-\infty}^{Q_i} F_{D_i}(Q)\Big] \quad (12)$$

Considering the strategy where the supplier exclusively prioritizes the quantity, the optimal quantity for maximizing its global expected profit within the whole network based on Eq. (12) is presented in the Eq. (13):

$$\widehat{Q_{is}}^{*} = F_{D_i}^{-1}\left(\frac{(\nu-\theta(\nu+\tau)-c_s-e_s+l+\delta\psi_i nw)}{(w-l)}\right) \quad (13)$$

With some algebra the optimal price w^* for the supplier according to $(\widehat{Q_{is}}^{*})$ is presented in the Eq. (14):

$$w^* = \frac{l(F_{D_i}(\widehat{Q_{is}}^{*})+1)+\nu-\theta(\nu+\tau)-c_s-e_s}{F_{D_i}(\widehat{Q_{is}}^{*})-\delta\psi_i n} \quad (14)$$

Proof. Maximum supplier's global expected profit is sought by deriving the expected profit function $E(\pi_s(Q))$.

$$\frac{\partial E(\pi_s(Q))}{\partial Q} = n\big[(\nu - \theta(\nu+\tau) - c_s - e_s + l + \delta\psi_i nw) + (l - w)\,F_{D_i}(Q)\big]$$

The second derivative of the global expected profit function for supplier with respect to (Q) is:

$$\frac{\partial^2 \mathrm{E}(\pi_s(Q))}{\partial^2 Q} = -n\big[(w-l)f_{D_i}(Q)\big]$$

We have: $\frac{\partial^2 \mathrm{E}(\pi_s(Q))}{\partial^2 Q} < 0$ thus, the function admits a maximum. Since the wholesale price (w) of the supplier is significantly higher than the depreciation cost (l) and the density function f_{D_i} is positive.

IV. Numerical Analysis

This section conducts a numerical analysis to draw conclusions on sustainability and resilience in logistics supply chains, emphasizing quantity-based strategies and sustainability practices within defined constraints. Due to demand's probabilistic nature in the model, forecasts may be inaccurate. Two configurations, cooperative and non-cooperative, are analyzed considering both uniform and normal demand distributions.

The numerical parameters and datasets presented in Tables I and II are utilized for this analysis and pertain to both the store and the supplier. These have been selected after a thorough review of existing literature [4], making sure they conform to methodologies. To enhance the overall validity and reliability of our numerical approach, we carefully select these values to align with the specific assumptions stated in our study.

Table I and Table II also present the outcomes of the proposed model, considering two distinct demand distribution functions: the uniform and the normal, respectively, along with two distinct configurations for the store: the cooperative configuration and the non-cooperative one. In order to effectively use the dataset, it was necessary to consider six scenarios, where the main variable parameter was the sustainability costs (e_i) and (e_s). Indeed, the sustainability cost, as a variable parameter, is manipulated to observe its impact on optimal quantities and expected profits.

TABLE I. DATA SETS AND RESULTS OF APPLYING PROPOSED MODELS ON NUMERICAL EXAMPLES FOR A UNIFORM DISTRIBUTION

The store's non-cooperative case: uniform distribution $c_i = 20,\ p_i = 130, \omega_i = 40, l = 4, z = 80,\ D\sim(a,b) = (100,200)$			
Scenario	e_i	Q_i^{*NC}	$E^{NC}(\pi_i)$
1	59	153,33	3330,00
2	60	152,17	3221,74
3	61	151,06	3111,70
4	62	150,00	3000,00
5	63	148,98	2886,73
6	64	148,00	2772,00

The store's cooperative case: uniform distribution $c_i = 20, p_i = 130, \omega_i = 60, e' = 20,\ p' = 90,\ \omega' = 110,\ \varphi = 10\%,$ $D \sim (a, b) = (100, 200)$			
Scenario	e_i	Q_i^{*CO}	$E^{CO}(\pi_i)$
1	59	109,01	4770,51
2	60	109,09	4661,55
3	61	109,17	4553,33
4	62	109,26	4445,89
5	63	109,35	4339,24
6	64	109,43	4233,42
The supplier case: uniform distribution $c_s = 23, w = 130, n = 3, v = 77, \theta = 65\%,\ \tau = 11,\ \psi = 40\%, \delta = 30\%,$ $l = 10,\ D \sim (a, b) = (100, 200)$			
Scenario	e_s	$\widehat{Q_{is}}^*$	$E(\pi_s)$
1	12	128,00	11150,40
2	13	123,00	10697,40
3	14	118,00	10274,40
4	15	113,00	9881,40
5	16	108,00	9518,40
6	17	103,00	9185,40

TABLE II. DATA SET AND RESULTS OF APPLYING PROPOSED MODELS ON NUMERICAL EXAMPLES FOR A NORMAL DISTRIBUTION

The store's non-cooperative case: normal distribution $c_i = 20,\ p_i = 130,\ \omega_i = 40, l = 4, z = 80,\ N \sim (\mu, \sigma) = (100, 30)$			
Scenario	e_i	Q_i^{*NC}	$E^{NC}(\pi_i)$
1	59	102,51	1636,69
2	60	101,64	1549,72
3	61	100,80	1462,31
4	62	100,00	1374,48
5	63	99,23	1286,25
6	64	98,50	1197,66
The store's cooperative case: normal distribution $c_i = 20, p_i = 130, \omega_i = 60, e' = 20,\ p' = 90,\ \omega' = 110,\ \varphi = 10\%,$ $N \sim (\mu, \sigma) = (100, 30)$			
Scenario	e_i	Q_i^{*CO}	$E^{CO}(\pi_i)$
1	59	59,79	4197,64
2	60	59,94	4233,95
3	61	60,10	4269,66
4	62	60,25	4305,46
5	63	60,41	4340,65
6	64	60,57	4375,57
The supplier case: normal distribution $c_s = 23, w = 130, n = 3, v = 77,\ \theta = 65\%,\ \tau = 11, \psi = 40\%,\ \delta =$ $30\%, l = 10, N \sim (\mu, \sigma) = (100, 30)$			
Scenario	e_s	$\widehat{Q_{is}}^*$	$E(\pi_s)$
1	12	82,51	3452,49
2	13	77,83	2873,65
3	14	72,54	2323,49
4	15	66,21	1798,30
5	16	57,85	1290,32
6	17	43,58	760,04

C. Profit Optimization and Sustainability

In this subsection, the examination of the expected profits of the supplier and the store under various scenarios, considering uniform and normal distribution cases, is conducted. Additionally, the optimal quantity of the aforementioned logistics actors in these distributions across non-cooperative and cooperative configurations is illustrated.

Given the nature of demand (D_i), when it follows a uniform distribution, the optimal quantities for the store and the supplier exceed those associated with demand following a inormal distribution, as demonstrated in Table I and Table II. Similarly, the expected profits generated by the supplier and the store in non-cooperative and cooperative configurations are higher when demand (D_i) follows a uniform distribution compared to a normal distribution, as presented in Table I and Table II. In a distribution network comprising multiple stores and a supplier, when the demand (D_i) follows a uniform distribution, it is advantageous for both the store and the supplier to have a regular demand to maximize profit. However, in the case of a normal distribution, the demand may not be regular.

Comparing the store's expected profit in both cooperative and non-cooperative scenarios, regardless of the demand nature, whether it follows a uniform or normal distribution, the cooperative scenario yields higher expected profit, as depicted in Tables I and II. Therefore, the store has an interest in cooperating to maximize its expected profit. The proposed cooperative configuration actively promotes store collaboration by sharing central warehouse-related costs and pooling resources, particularly the surplus quantities $(Q_i - D_i)$, which are returned and resold to the central warehouse, resulting in a reduction of depreciation (l) and stockout (z) costs.

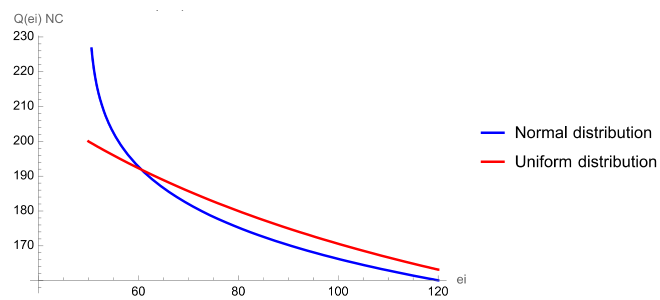

Fig. 3. The store's optimal quantity variation by store sustainability cost (e_i) for the cooperative configuration.

Fig. 3 depicts the evolution of the store's optimal quantity (Q_i^{*NC}) with the store sustainability cost (e_i) increase in a non-cooperative configuration. The optimal quantity (Q_i^{*NC}) for the normal distribution initially is significantly higher than that of the uniform distribution and decreases rapidly with the increase in (e_i). Similarly, it is possible to determine the optimal sustainability cost (e_i) corresponding to the intersection of the two curves, especially in the absence of information on demand evolution.

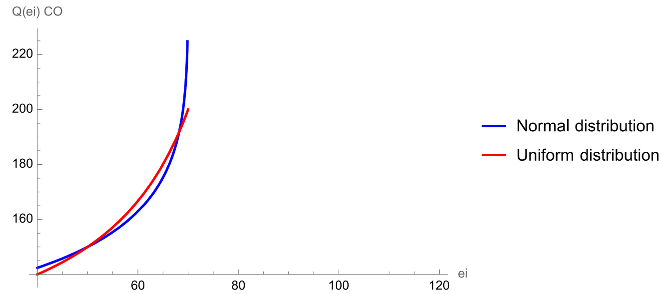

Fig. 4. The store's optimal quantity variation by store sustainability cost (e_i) for the cooperative configuration.

Fig. 4 shows the evolution of the store's optimal quantity (Q_i^{*CO}) with the store sustainability cost (e_i) increase in a non-cooperative configuration. The optimal quantity (Q_i^{*CO}) increases substantially with the rise in sustainability cost (e_i), regardless of the distribution type. However, this increase is particularly significant when dealing with a normal distribution. Beyond a certain value of (e_i) (around 70), the optimal quantity becomes insensitive to a large increase in (e_i).

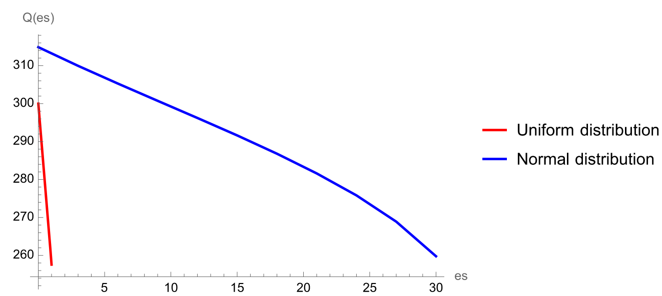

Fig. 5. The supplier's optimal quantity variation by supplier sustainability cost (e_s).

The optimal quantity $(\widehat{Q_{is}}^*)$ in the supplier's case decreases with the rise of the supplier's sustainability cost (e_s), as depicted in Fig. 5. A distinct contrast is observable between the normal and uniform distributions. In the case of the uniform distribution, the optimal quantity $(\widehat{Q_{is}}^*)$ for the supplier has decreased significantly following a slight variation in the sustainability cost (e_s). Conversely, in the case of a normal distribution, the optimal quantity $(\widehat{Q_{is}}^*)$ gradually decreases with a larger variation in the sustainability cost (e_s).

The correlation between sustainability costs and expected profit remains consistently evident. Fig. 6, 7, and 8 illustrate the expected profit evolution concerning quantity in the case of a normal distribution. In the non-cooperative scenario, the store's expected profit experiences a notable decline with both high sustainability costs (e_i) and quantity, as depicted in Fig. 6. The higher the sustainability cost (e_i), the more pronounced the decrease in expected profit. Between $(e_i = 30)$ and $(e_i = 33)$, the expected profit turns negative for quantities greater than 60. The store benefits from maintaining a sustainability cost (e_i) that is not excessively high to maximize expected profit in the non-cooperative configuration.

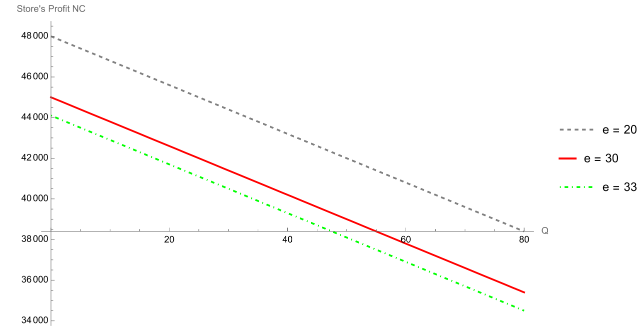

Fig. 6. The impact of store sustainability cost (e_i) on the variation of store's expected profit by quantity of the non-cooperative configuration in a normal distribution case.

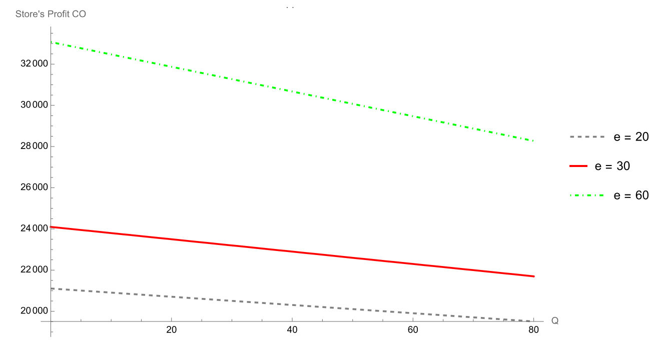

Fig. 7. The impact of store sustainability cost (e_i) on the variation of store's expected profit by quantity of the cooperative configuration in a normal distribution case.

On the other hand, the cooperative scenario, shown in Fig. 7, exhibits different outcomes. The higher the sustainability cost (e_i), the greater the expected profit. A decrease of the expected profit as quantity (Q_i) rises is noticeable, especially in the case of high sustainability cost (e_i). The higher the sustainability cost, the greater the expected profit. Between $(e_i = 30)$ and $(e_i = 60)$, there is a significant increase in the store's expected profit. The store benefits from increasing its sustainability cost (e_i) to maximize its expected profit in the cooperative scenario.

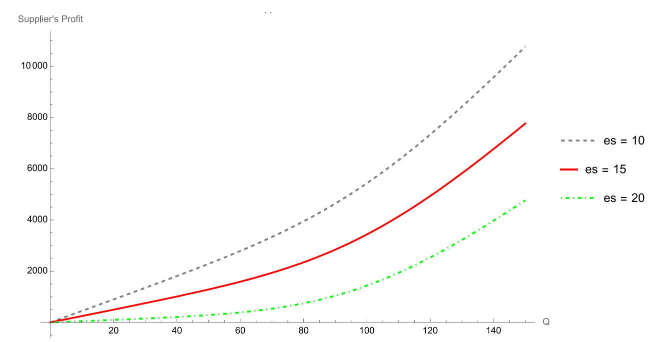

Fig. 8. The impact of supplier sustainability cost (e_s) on the variation of supplier's expected profit by quantity in a normal distribution case.

On the contrary, in Fig. 8, the supplier's expected profit rises with an increase in quantity (Q_i). Nevertheless, a higher sustainability cost for the supplier (e_s) leads to a decrease in the supplier's expected profit. This explains the supplier's interest in selling more products while managing its sustainability cost (e_s).

D. Profit Optimization and Resilience

In this subsection, the aim is to scrutinize the profitability for both the supplier and the store across various demand scenarios, the uniform and normal distribution case. Furthermore, Additionally, the supplier's resilience based on foreign products and security stock is investigated.

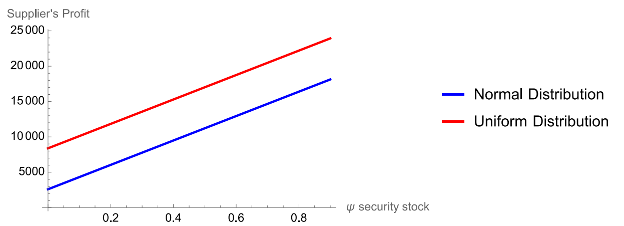

Fig. 9. The influence of security stock (ψ_i) ratio on supplier's expected profit in a uniform and normal distribution cases.

Fig. 9 illustrates the impact of the security stock ratio (ψ_i) allocated to the store by the supplier. The influence indicates a significant increase in the supplier's expected profit with an elevation in the security stock (ψ_i), considering that the costs of the security stock are carried by the store. The distinction between normal and uniform distributions is clearly apparent. The uniform distribution results in higher supplier expected profit with an increased security stock ratio (ψ_i). However, the trend of the curves remains consistent for both distributions. It is more beneficial for the supplier to have demand following a normal distribution in order to maximize expected profit.

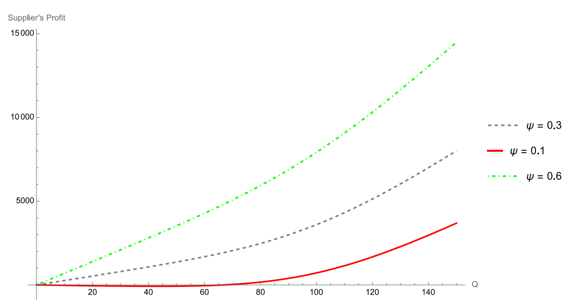

Fig. 10. The impact of security stock ratio (ψ_i)on the variation of supplier's expected profit by quantity in a normal distribution case.

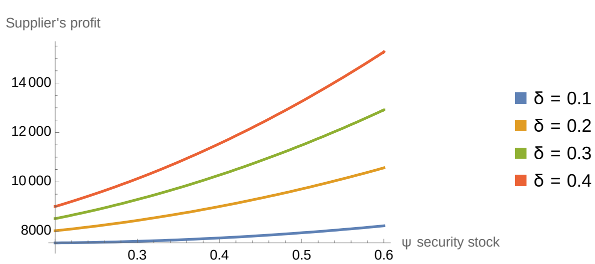

Fig. 11. The influence of the ratio of holding products on supplier's expected profit variation by security stock in a uniform distribution case.

Similarly, in the case of a uniform distribution, Fig. 10 and Fig. 11 illustrates the influence of the ratio of the supplier's wholesale price dedicated to holding products (δ) on expected profit. A higher ratio (δ) of holding products correlates with a greater supplier's expected profit. As the costs related to security stock and holding are carried by the store, the supplier has an interest in proposing to the store high ratios of security stock (ψ_i) and holding costs (δ).

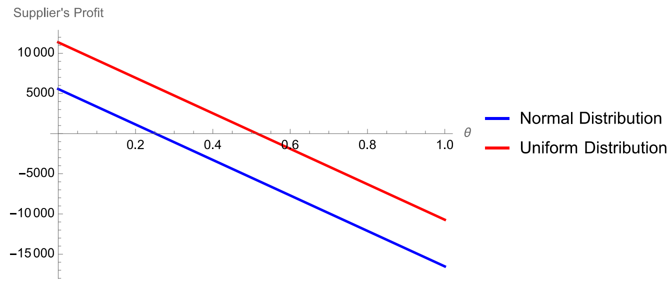

Fig. 12. The influence of foreign product ratio (θ) on supplier's expected profit in a uniform and normal distribution cases.

As illustrated in Fig. 12 and Fig. 13, an increase in (θ) results in a decline in the supplier's expected profit due to the imposition of custom fees (τ) by the government.

In the case of the uniform distribution, expected profit is higher than in the normal distribution with the variation of (τ), as depicted in Fig. 12. Both distributions exhibit the same trend. For the supplier to be more resilient, it is advantageous for them to have demand following a uniform distribution. This is because in the case of a normal distribution, the expected profit is negative, leaving the supplier with no option to import more products from abroad.

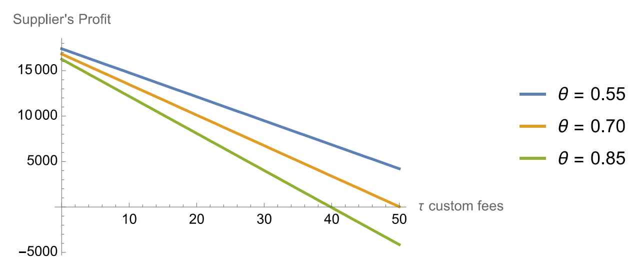

Fig. 13. The impact of foreign product ratio on the variation of supplier's expected profit by custom fees (τ) in a normal distribution case.

Fig. 13 illustrates that expected profit sharply decreases with higher customs fees (τ) and a higher ratio of foreign products (θ). As the integration of foreign products (θ) increases, the supplier experiences a proportional decline in expected profit. Initially, the integration rate (θ) is perceptible when the custom fees (τ) are low. It is more beneficial for the supplier to have a low foreign product integration rate (θ) when custom fees (τ) are high. However, it is crucial for the supplier to maintain the option of importing foreign products (θ) to enhance upstream resilience through diversified sourcing channels. As a regulatory body, the government can act by increasing customs fees (τ) at reasonable rates to maintain a local equilibrium.

V. Results and Discussion

The imperative recognition of sustainability and resilience as crucial pillars underscores their role in ensuring the long-term adaptability and viability of economic strategies. The literature emphasizes the economic significance of these concepts, highlighting the necessity for a comprehensive examination of how quantity-based strategies and effective uncertainty management can collectively strengthen the robustness and adaptability of supply chains, ultimately contributing to enhanced profitability.

Results shows that in scenarios where demand (D_i) is uniformly distributed, the store and the supplier tend to have higher optimal quantities compared to when demand follows a normal distribution. Furthermore, expected profits for both the supplier and the store are generally higher in both non-cooperative and cooperative setups when demand (D_i) follows a uniform distribution. Having a regular demand pattern is advantageous for maximizing expected profit, especially when demand (D_i) follows a uniform distribution. However, with a normal distribution, demand variability may disrupt this advantage. For instance, common or generic products often exhibit uniform demand patterns, whereas products from large-scale distribution may demonstrate normal demand distribution under certain circumstances. In distribution networks aimed at delivering products to markets characterized by stochastic demand following a uniform distribution, the main actors of the logistics network (stores and suppliers) enjoy significantly more favorable expected profits compared to demand following a normal distribution.

The examination of store's expected profit in both cooperative and non-cooperative configuration, regardless of the demand nature, whether it follows a uniform or normal distribution, reveals that the cooperative scenario consistently yields higher expected profits. Consequently, the store is incentivized to engage in cooperation to maximize its profit. The conclusion is consistent with previous studies [48], [49]. The proposed cooperative configuration actively fosters store collaboration by sharing central warehouse-related costs and pooling resources, particularly the surplus quantities $(Q_i - D_i)$, which are returned and resold to the central warehouse, resulting in a reduction of depreciation (l) and stockout (z) costs. Given the constraints of resilience and sustainability, cooperation between stores remains the best approach to guarantee maximum expected profit.

Sustainability significantly influences both the store's and the supplier's expected profits, particularly noteworthy is its impact when dealing with high quantities. These results are consistent with previous studies [10], [49], [50]. In the non-cooperative scenario, the store's optimal quantity $({Q_i}^{*NC})$ decreases with a higher sustainability cost (e_i), similarly for the supplier, with its sustainability cost (e_s), the optimal quantity $(\widehat{Q_{is}}^{*})$ decreases with a perceptible difference between the normal and uniform distributions. However, within the cooperative store scenario, this effect is mitigated, the store's optimal quantity $({Q_i}^{*CO})$ increases with a high sustainability cost (e_i). In the absence of information on demand evolution, the intersection of the two curves of the normal and uniforms distributions, determine the optimal store sustainability cost (e_i). Furthermore, sustainability costs $(e_i), (e_s)$ tend to diminish supplier's expected profit and store's expected profit for the non-cooperative configuration, emphasizing the crucial significance of cooperation in enhancing store's expected profit and alleviating the sustainability cost impact. This underscores the critical importance for both the supplier and the store to carefully consider and manage sustainability costs in the decision-making process. Consequently, sustainability efforts within the logistics network emerge as genuine strategies for network actors, enabling them to remain competitive and viable. This becomes clearer when stores decide to cooperate by reselling surplus quantities.

Resilience is a central element in the proposed model, supported by the supplier through two actions. Firstly, by mitigating downstream supply chain risks through the allocation of security stock (ψ_i) to each store. Secondly, by addressing upstream supply chain risks through the importation of foreign products (θ). The results demonstrate that, even as the quantity increases in the case of a low security stock ratio (ψ_i), expected profit rises, with a more pronounced impact at higher (ψ_i) ratios. Additionally, a higher ratio (δ) of holding products correlates with greater supplier expected profit. As the costs related to security stock and holding are borne by the store, the supplier has an interest in proposing high ratios of security stock (ψ_i) and holding costs (δ) to the store. The strategy pursued by the supplier regarding resilience, which involves negotiating the level of security stock with the store, appears opportune as it has a significant impact on the supplier's expected profit, especially when the number of stores is substantial. These results align with the findings of a prior research [51].

Moreover, the analysis explores the influence of customs fees and the integration of foreign products (θ) on the supplier's expected profit, indicating a decline with higher customs fees (τ) and an increased ratio of foreign products. The use of foreign products negatively affects this expected profit, especially in the absence of government regulation policies such as the application of customs fees (τ). This finding align with previous studies [7], [9], [10]. The recommendation to maintain the option of importing foreign products (θ)underscores the importance of diversified sourcing channels for upstream resilience. The suggestion for government intervention in regulating customs fees (τ) aims to balance local equilibrium.

VI. Conclusion

In today's fiercely competitive global market and an increased uncertainty, supply chain resilience and sustainability have become top priorities, to adapt quickly to disruptions while meeting sustainability goals. To address these challenges, supply chain actors are implementing strategies to bolster the sustainability and resilience of their operations. This research investigates interconnected issues within supply chains, offering insights to develop resilient, sustainable solutions. It explores quantity-based strategies for optimizing expected profits while integrating sustainability and resilience principles, ensuring alignment with sustainability requirements while maintaining competitiveness. The study aims to identify scenarios that offer significant advantages for maximizing expected profits while adhering to sustainability standards.

The study examines a monopolistic, sustainable, and resilient supply chain network operating in an uncertain environment with two tiers: suppliers and multiple stores. A stochastic model is developed to deal with demand uncertainty and maximize supplier and store expected profits. Two configurations are proposed for the store. The non-cooperative configuration, individual where stores and the supplier independently optimize expected profits based on delivery quantities, and the cooperative configuration where stores collaborate to jointly maximize expected profits while reducing stockout risks through a central warehouse for surplus returns. Various strategies are implemented by supply chain actors, addressing resilience, utilizing dedicated security stocks, and diversifying product sources. Sustainability is integrated through eco-friendly practices initiated by the supplier and stores, with cooperation enhancing resilience via a central warehouse as a backup supplier. Return logistics are managed to minimize waste and product depreciation [14], [15], promoting responsible inventory management [14], [15].

The findings highlight insights regarding supply chain dynamics in the face of uncertainty and sustainability imperatives. Firstly, it is observed that in a distribution network designed to deliver products to markets marked by stochastic demand that follows a uniform distribution, the main players in the logistics network (stores and supplier) have higher expected profit compared with demand that follows the normal distribution. Given the constraints of resilience and sustainability, cooperation between stores emerges as a strategy for maximizing expected profit, in particular by mitigating sustainability costs. Moreover, sustainability efforts applied in the logistics network constitute genuine strategies for the actors in the logistics network, enabling them to remain competitive and viable. This becomes clearer when stores decide to cooperate by reselling surplus quantities. In terms of resilience, the supplier's strategy of negotiating a security stock level with the store seems to be an opportune one, since it has a considerable impact on the supplier's expected profit, particularly when the number of stores is large. On the other hand, the use of foreign products has a negative impact on this expected profit, especially in the absence of a regulatory policy on the part of the government, which consists of enforcing a minimum stock level.

The proposed model provides managerial advantages by facilitating cooperation among stores through the resale of surplus quantities to the central warehouse, thereby reducing costs associated with stockouts and product depreciation while maximizing expected profits. Moreover, determining the ratio of imported foreign products is a crucial decision for suppliers, with errors in decision-making potentially diminishing expected profits. Our model assists managers in making informed choices regarding the determination of foreign product ratio to import. Additionally, the cooperative model encourages stores to collaborate and pool their resources.

It is essential to understand the limitations of our research, enabling researchers to accurately interpret our findings and identify potential avenues for further investigation. The first limitation of the model concerns the consideration of a single supplier. Indeed, the discussed model only accounts for one supplier responsible for supplying all the stores. Consequently, this present a significant risk to the resilience of the entire supply chain. Therefore, it would be advisable to propose, in future work, two-echelon supply chain models that involve multiple suppliers to better reflect logistical reality. Furthermore, the work conducted does not take into account the competitive aspect at the store level. Indeed, to simplify the study, we have assumed a monopolistic market (each store has a monopoly in its trade area). Therefore, it would be interesting to revisit the model by assuming a single oligopolistic market.

As a perspective of this work, cooperation between the supplier and the stores could be an opportunity to further improve the profits of these actors by selling surplus quantities from the supplier to the central warehouse. This is an avenue that could further explore the value of cooperation in promoting sustainability and resilience.

ACKNOWLEDGMENT

This research paper was conducted by the LASTIMI laboratory of Mohammed V University in Rabat, High School of Technology of SALE and supported by ESITH Morocco. The authors are sincerely grateful to CELOG team and each person who have helped in any way to the accomplishment of this study.

DECLARATION OF COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

[1] D. Saidi, J. El Alami, et M. Hlyal, « Sustainable Supply Chain Management: review of triggers, challenges and conceptual framework. », in IOP Conference Series: Materials Science and Engineering, IOP Publishing, 2020, p. 012054.

[2] D. Saidi, J. E. Alami, et M. Hlyal, « Building Sustainable Resilient Supply Chains in Emerging Economies: Review of Motivations and Holistic Framework », IOP Conf. Ser.: Earth Environ. Sci., vol. 690, no 1, p. 012057, mars 2021, doi: 10.1088/1755-1315/690/1/012057.

[3] W. Liu et al., « Pricing and collection decisions of a closed-loop supply chain with fuzzy demand », International Journal of Production Economics, vol. 245, p. 108409, mars 2022, doi: 10.1016/j.ijpe.2022.108409.

[4] R. Tat, J. Heydari, et M. Rabbani, « A mathematical model for pharmaceutical supply chain coordination: Reselling medicines in an alternative market », Journal of Cleaner Production, vol. 268, p. 121897, sept. 2020, doi: 10.1016/j.jclepro.2020.121897.

[5] M.-B. Jamali, M. Rasti-Barzoki, et J. Altmann, « A game-theoretic approach for investigating the competition between energy producers under the energy resilience index: A case study of Iran », Sustainable Cities and Society, vol. 95, 2023, doi: 10.1016/j.scs.2023.104598.

[6] A. Hafezalkotob, S. Arisian, R. Reza-Gharehbagh, et L. Nersesian, « Joint impact of CSR policy and market structure on environmental sustainability in supply chains », Computers & Industrial Engineering, vol. 185, p. 109654, nov. 2023, doi: 10.1016/j.cie.2023.109654.

[7] S. P. Parvasi et A. A. Taleizadeh, « Competition pricing between domestic and foreign manufacturers: a bi-level model using a novel hybrid method », Sadhana - Academy Proceedings in Engineering Sciences, vol. 46, no 2, 2021, doi: 10.1007/s12046-021-01627-y.

[8] H. Rajabzadeh, A. Arshadi Khamseh, et M. Ameli, « A Game-Theoretic Approach for Pricing Considering Sourcing, Andrecycling Decisions in a Closed-Loop Supply Chain Under Disruption », Communications in Computer and Information Science, vol. 1458 CCIS, p. 137-157, 2021, doi: 10.1007/978-3-030-89743-7_9.

[9] S. P. Parvasi, A. A. Taleizadeh, et L. E. Cárdenas-Barrón, « Retail price competition of domestic and international companies: A bi-level game theoretical optimization approach », RAIRO - Operations Research, vol. 57, no 1, p. 291-323, 2023, doi: 10.1051/ro/2023007.

[10] D. Saidi, A. A. Bassou, J. E. Alami, et M. Hlyal, « Sustainability and Resilience Analysis in Supply Chain Considering Pricing Policies and Government Economic Measures », International Journal of Advanced Computer Science and Applications (IJACSA), vol. 15, no 1, Art. no 1, 33/30 2024, doi: 10.14569/IJACSA.2024.0150127.

[11] A. Jafari-Nodoushan, M. H. D. Sadrabadi, M. Nili, A. Makui, et R. Ghousi, « Designing a sustainable disruption-oriented supply chain under joint pricing and resiliency considerations: A case study », Computers and Chemical Engineering, vol. 180, 2024, doi: 10.1016/j.compchemeng.2023.108481.

[12] M. Gharegozlu, A. Ghaderi, et A. Hossein Seddighi, « Location-pricing problem in a two-echelon supply chain: A behavioral game-theoretic approach », Computers & Operations Research, vol. 163, p. 106486, mars 2024, doi: 10.1016/j.cor.2023.106486.

[13] D. Saidi, K. Jharni, J. Alami, et M. Hlyal, « What Modeling Approaches Used For A Sustainable Resilient Supply Chain », Journal of Theoretical and Applied Information Technology, vol. Vol.100, p. 35, déc. 2022, doi: 10.5281/zenodo.7542949.

[14] S. Liu, L. G. Papageorgiou, et N. Shah, « Optimal design of low-cost supply chain networks on the benefits of new product formulations », Computers & Industrial Engineering, vol. 139, p. 106189, janv. 2020, doi: 10.1016/j.cie.2019.106189.

[15] H. H. Latif, S. K. Paul, et A. Azeem, « Ordering policy in a supply chain with adaptive neuro-fuzzy inference system demand forecasting », International Journal of Management Science and Engineering Management, vol. 9, no 2, p. 114-124, avr. 2014, doi: 10.1080/17509653.2013.866332.

[16] P. Rafigh, A. A. Akbari, H. M. Bidhandi, et A. H. Kashan, « A sustainable supply chain network considering lot sizing with quantity discounts under disruption risks: centralized and decentralized models », J Comb Optim, vol. 44, no 3, p. 1387-1432, oct. 2022, doi: 10.1007/s10878-022-00891-w.

[17] E. B. Tirkolaee, P. Abbasian, et G.-W. Weber, « Sustainable fuzzy multi-trip location-routing problem for medical waste management during the COVID-19 outbreak », Science of The Total Environment, vol. 756, p. 143607, févr. 2021, doi: 10.1016/j.scitotenv.2020.143607.

[18] M. Akbari-Kasgari, H. Khademi-Zare, M. B. Fakhrzad, M. Hajiaghaei-Keshteli, et M. Honarvar, « Designing a resilient and sustainable closed-loop supply chain network in copper industry », Clean Technologies and Environmental Policy, vol. 24, no 5, p. 1553-1580, 2022, doi: 10.1007/s10098-021-02266-x.

[19] E. B. Tirkolaee, N. S. Aydın, M. Ranjbar-Bourani, et G.-W. Weber, « A robust bi-objective mathematical model for disaster rescue units allocation and scheduling with learning effect », Computers & Industrial Engineering, vol. 149, p. 106790, nov. 2020, doi: 10.1016/j.cie.2020.106790.

[20] M. Safaeian, A. M. Fathollahi-Fard, G. Tian, Z. Li, et H. Ke, « A multi-objective supplier selection and order allocation through incremental discount in a fuzzy environment », Journal of Intelligent & Fuzzy Systems, vol. 37, no 1, p. 1435-1455, janv. 2019, doi: 10.3233/JIFS-182843.

[21] A. Samadi, N. Mehranfar, A. M. Fathollahi Fard, et M. Hajiaghaei-Keshteli, « Heuristic-based metaheuristics to address a sustainable supply chain network design problem », Journal of Industrial and Production Engineering, vol. 35, no 2, p. 102-117, févr. 2018, doi: 10.1080/21681015.2017.1422039.

[22] D. Yang et T. Xiao, « Pricing and green level decisions of a green supply chain with governmental interventions under fuzzy uncertainties », Journal of Cleaner Production, vol. 149, p. 1174-1187, avr. 2017, doi: 10.1016/j.jclepro.2017.02.138.

[23] H. Pei, Y. Liu, et H. Li, « Robust Pricing for a Dual-Channel Green Supply Chain Under Fuzzy Demand Ambiguity », IEEE Transactions on Fuzzy Systems, vol. 31, no 1, p. 53-66, janv. 2023, doi: 10.1109/TFUZZ.2022.3181465.

[24] A. M. Fathollahi-Fard, M. Hajiaghaei-Keshteli, et S. Mirjalili, « Multi-objective stochastic closed-loop supply chain network design with social considerations », Applied Soft Computing, vol. 71, p. 505-525, oct. 2018, doi: 10.1016/j.asoc.2018.07.025.

[25] M. Johari et S.-M. Hosseini-Motlagh, « Coordination of social welfare, collecting, recycling and pricing decisions in a competitive sustainable closed-loop supply chain: a case for lead-acid battery », Ann Oper Res, juin 2019, doi: 10.1007/s10479-019-03292-1.

[26] Z. S. Hosseini, S. D. Flapper, et M. Pirayesh, « Sustainable supplier selection and order allocation under demand, supplier availability and supplier grading uncertainties », Computers and Industrial Engineering, vol. 165, 2022, doi: 10.1016/j.cie.2021.107811.

[27] S. Fakheri, Z. Bahrami-Bidoni, A. Makui, M. S. Pishvaee, et E. D. Santibanez Gonzalez, « A sustainable competitive supply chain network design for a green product under uncertainty: A case study of Iranian leather industry », Socio-Economic Planning Sciences, vol. 84, 2022, doi: 10.1016/j.seps.2022.101414.

[28] S. Fakheri, Z. Bahrami-Bidoni, A. Makui, M. S. Pishvaee, et E. D. Santibanez Gonzalez, « A sustainable competitive supply chain network design for a green product under uncertainty: A case study of Iranian leather industry », Socio-Economic Planning Sciences, vol. 84, 2022, doi: 10.1016/j.seps.2022.101414.

[29] A. Majidi, P. Farghadani-Chaharsooghi, et S. M. J. Mirzapour Al-E-Hashem, « Sustainable Pricing-Production-Workforce-Routing Problem for Perishable Products by Considering Demand Uncertainty; A Case Study from the Dairy Industry », Transportation Journal, vol. 61, no 1, p. 60-102, 2022, doi: 10.5325/TRANSPORTATIONJ.61.1.0060.

[30] Y. Kazancoglu, D. Yuksel, M. D. Sezer, S. K. Mangla, et L. Hua, « A Green Dual-Channel Closed-Loop Supply Chain Network Design Model », Journal of Cleaner Production, vol. 332, p. 130062, janv. 2022, doi: 10.1016/j.jclepro.2021.130062.

[31] R. Ghasemy Yaghin et Z. Farmani, « Planning a low-carbon, price-differentiated supply chain with scenario-based capacities and eco-friendly customers », International Journal of Production Economics, vol. 265, 2023, doi: 10.1016/j.ijpe.2023.108986.

[32] M. H. Dehghani Sadrabadi, A. Makui, R. Ghousi, et A. Jabbarzadeh, « An integrated optimization model for planning supply chains' resilience and business continuity under interrelated disruptions: a case study », Kybernetes, 2023, doi: 10.1108/K-04-2023-0547.

[33] B. Zahiri, J. Zhuang, et M. Mohammadi, « Toward an integrated sustainable-resilient supply chain: A pharmaceutical case study », Transportation Research Part E: Logistics and Transportation Review, vol. 103, p. 109-142, 2017, doi: 10.1016/j.tre.2017.04.009.

[34] M. M. Vali-Siar et E. Roghanian, « Sustainable, resilient and responsive mixed supply chain network design under hybrid uncertainty with considering COVID-19 pandemic disruption », Sustainable Production and Consumption, vol. 30, p. 278-300, 2022, doi: 10.1016/j.spc.2021.12.003.

[35] A. Mohammed, I. Harris, A. Soroka, et R. Nujoom, « A hybrid MCDM-fuzzy multi-objective programming approach for a G-resilient supply chain network design », Computers and Industrial Engineering, vol. 127, p. 297-312, 2019, doi: 10.1016/j.cie.2018.09.052.

[36] S. Rezapour, R. Z. Farahani, et M. Pourakbar, « Resilient supply chain network design under competition: A case study », European Journal of Operational Research, vol. 259, no 3, p. 1017-1035, 2017, doi: 10.1016/j.ejor.2016.11.041.

[37] A. Ghavamifar, A. Makui, et A. A. Taleizadeh, « Designing a resilient competitive supply chain network under disruption risks: A real-world application », Transportation Research Part E: Logistics and Transportation Review, vol. 115, p. 87-109, 2018, doi: 10.1016/j.tre.2018.04.014.

[38] G. Esenduran, A. Atasu, et L. N. Van Wassenhove, « Valuable e-waste: Implications for extended producer responsibility », IISE Transactions, vol. 51, no 4, p. 382-396, avr. 2019, doi: 10.1080/24725854.2018.1515515.

[39] W. Pan et M. Lin, « A Two-Stage Closed-Loop Supply Chain Pricing Decision: Cross-Channel Recycling and Channel Preference », Axioms, vol. 10, no 2, Art. no 2, juin 2021, doi: 10.3390/axioms10020120.

[40] D. Wen, T. Xiao, et M. Dastani, « Pricing and collection rate decisions in a closed-loop supply chain considering consumers' environmental responsibility », Journal of Cleaner Production, vol. 262, p. 121272, juill. 2020, doi: 10.1016/j.jclepro.2020.121272.

[41] R. Tat, J. Heydari, et M. Rabbani, « A mathematical model for pharmaceutical supply chain coordination: Reselling medicines in an alternative market », Journal of Cleaner Production, vol. 268, p. 121897, sept. 2020, doi: 10.1016/j.jclepro.2020.121897.

[42] L. Liu, C. Zhang, Z. Wang, et Y. Liu, « Green technology investment selection with carbon price and competition: One-to-many matching structure », Journal of Cleaner Production, vol. 434, p. 139893, janv. 2024, doi: 10.1016/j.jclepro.2023.139893.

[43] W. Liu et al., « Pricing and collection decisions of a closed-loop supply chain with fuzzy demand », International Journal of Production Economics, vol. 245, p. 108409, mars 2022, doi: 10.1016/j.ijpe.2022.108409.

[44] Z. Chen, A. W. A. Hammad, et M. Alyami, « Building construction supply chain resilience under supply and demand uncertainties », Automation in Construction, vol. 158, p. 105190, févr. 2024, doi: 10.1016/j.autcon.2023.105190.

[45] M. Shafiee, Y. Zare Mehrjerdi, et M. Keshavarz, « Integrating lean, resilient, and sustainable practices in supply chain network: mathematical modelling and the AUGMECON2 approach », International Journal of Systems Science: Operations & Logistics, vol. 9, no 4, p. 451-471, oct. 2022, doi: 10.1080/23302674.2021.1921878.

[46] M. Babagolzadeh, A. Shrestha, B. Abbasi, Y. Zhang, A. Woodhead, et A. Zhang, « Sustainable cold supply chain management under demand uncertainty and carbon tax regulation », Transportation Research Part D: Transport and Environment, vol. 80, p. 102245, mars 2020, doi: 10.1016/j.trd.2020.102245.

[47] H. Rau, S. Daniel Budiman, et C. N. Monteiro, « Improving the sustainability of a reverse supply chain system under demand uncertainty by using postponement strategies », Waste Management, vol. 131, p. 72-87, juill. 2021, doi: 10.1016/j.wasman.2021.05.018.

[48] G. Lyu, M. Zhao, Q. Ji, et X. Lin, « Improving resilience via capacity allocation and strategic pricing: Co-opetition in a shipping supply chain », Ocean and Coastal Management, vol. 244, 2023, doi: 10.1016/j.ocecoaman.2023.106779.

[49] Z. Yanju, H. Fengying, et Z. Zhenglong, « Study on joint contract coordination to promote green product demand under the retailer-dominance », Journal of Industrial Engineering and Engineering Management, vol. 34, no 2, p. 194-204, 2020, doi: 10.13587/j.cnki.jieem.2020.02.021.

[50] X. Chen, X. Wang, V. Kumar, et N. Kumar, « Low carbon warehouse management under cap-and-trade policy », Journal of Cleaner Production, vol. 139, p. 894-904, déc. 2016, doi: 10.1016/j.jclepro.2016.08.089.

[51] A. A. Taleizadeh, A. Ghavamifar, et A. Khosrojerdi, « Resilient network design of two supply chains under price competition: game theoretic and decomposition algorithm approach », Operational Research, vol. 22, no 1, p. 825-857, 2022, doi: 10.1007/s12351-020-00565-7.