Supply chain coordination using consignment sales-vendor managed inventory (CS-VMI) contract

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Metadata of the article that will be visualized in OnlineFirst

ArticleTitle	Supply chain coordination using consignment sales-vendor managed inventory (CS-VMI) contract
Article Sub-Title	
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Journal Name	Operations Management Research

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Schedule	Received	26 Jul 2023
	Revised	31 Mar 2025
	Accepted	2 Apr 2025

Abstract

The purpose of this paper is to study the effectiveness of consignment sales – vendor-managed inventory (CS-VMI) contract between the consignor (manufacturer) and the consignee (retailer). The research explores how such a contract can enhance supply chain performance, primarily when supplying products with a short selling season. Specifically, it aims to establish settings for demand variability and cost structures under which the CS-VMI contract would benefit stakeholders. Building on the traditional newsvendor model, the paper formulates an optimal CS-VMI policy wherein the consignor (manufacturer) places inventory with the consignee (retailer) to increase market exposure. In contrast, the consignee pays the consignor only upon the sales of the product. The research demonstrates analytically how the commission rate can be derived and negotiated to enable risk hedging by the consignee and make the CS-VMI contract incentive-aligned and equitable for both parties. Numerical results reveal that the optimal consignment inventory is contingent on demand variability, the loss of goodwill penalty, and the commission rate.

Keywords (separated by '-'): Supply chain coordination - Consignment sales - Vendor-managed inventory - Newsvendor - Commission rate

Footnote Information

Operations Management Research
https://doi.org/10.1007/s12063-025-00549-w

ORIGINAL RESEARCH

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The purpose of this paper is to study the effectiveness of consignment sales – vendor-managed inventory (CS-VMI) contract between the consignor (manufacturer) and the consignee (retailer). The research explores how such a contract can enhance supply chain performance, primarily when supplying products with a short selling season. Specifically, it aims to establish settings for demand variability and cost structures under which the CS-VMI contract would benefit stakeholders. Building on the traditional newsvendor model, the paper formulates an optimal CS-VMI policy wherein the consignor (manufacturer) places inventory with the consignee (retailer) to increase market exposure. In contrast, the consignee pays the consignor only upon the sales of the product. The research demonstrates analytically how the commission rate can be derived and negotiated to enable risk hedging by the consignee and make the CS-VMI contract incentive-aligned and equitable for both parties. Numerical results reveal that the optimal consignment inventory is contingent on demand variability, the loss of goodwill penalty, and the commission rate.

Keywords Supply chain coordination · Consignment sales · Vendor-managed inventory · Newsvendor · Commission rate

1 Introduction

One of the major challenges facing businesses in the 21 st century is the shrinking life cycle of products. This is true in companies that manufacture and deliver high-fashion goods, electronic devices, or seasonal products (Shen et al. 2019). The approaches applied to manage short life-cycle products can also be used by grocery retailers carrying perishable items, such as dairy products and fresh foods. For businesses, this presents the dual challenge of meeting uncertain demand within a short selling season while facing pressure to shorten supply lead times (Wu et al. 2012) and accelerate product development to keep pace with the shrinking product life cycles (Beamon 2008).

Companies realize that time has become one of the most crucial dimensions of competitive priorities in the global marketplace. The focal point of business operations in the last few decades has shifted from cost-based and quality-based priorities of the 20 th century to time-based competition (Olhager 2013; Jacobs and Weston 2007). Further, with the supply network expanding beyond one's plants and country borders in muti-tiered supply chains, businesses find it hard to operate with the shrinking time dimension. Now, adding new realities of risks that range from emerging technologies and supply disruptions to geopolitical risks and protectionism, companies are left with only a few options to stay resilient and competitive at the same time (Salama and McGarvey 2023). The COVID- 19 pandemic underscored the critical importance of supply chain resilience, as heightened interdependencies across multiple tiers of suppliers amplified disruptive risks throughout the global network, threatening business continuity and competitiveness. Kazancoglu et al. (2022) discuss the importance of stakeholder engagement needed to ensure the resilience of a multi-tiered vaccine supply chain whose vulnerability can be easily exposed, as witnessed during the COVID- 19 pandemic.

Many businesses risk losing their competitive edge when they fail to respond swiftly to market demands, especially amid the uncertainties and risks inherent in today's global business environment. However, it should also be noted that competitiveness is no longer restricted to one's own business. It entails how one's supply chain can stack up to its competitors' supply

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chain, as observed in how Volkswagen's entire supply chain operates and competes against Ford's or Toyota's supply chains in the European market (Gaultier and Marcello 2021). With the increasing significance of buyer-supplier bonds, companies benefit from their partners' resilience capability (Durach et al. 2020), further enhancing the overall supply chain performance. Working effectively in collaboration with one's partners has indeed become an essential condition for any business to stay resilient in a highly disruptive global business ecosystem (Tang et al. 2018; Zhao et al. 2017). Although there is evidence to show that businesses rarely look beyond their direct buyers and suppliers (Primo 2010), companies realize that developing collaborative relationships has become an industry-wide mandate to remain competitive (Mesa and Galdeano-Gomez 2015). This realization is even more critical for products facing a short selling season, with buyers treating lead time as a primary supplier selection criterion (Sarkar et al. 2022). For these products (e.g., perishables, fashion goods, high-tech gadgets, etc.), developing an agile and incentive-aligned coordination mechanism is more crucial than ever as each business has a limited time window to maximize its potential (Son and Enstroem 2021).

This paper extends the work by Son (2019), which emphasizes the need for effective supply chain coordination for products with limited shelf-life. Utilizing the newsvendor approach, Son (2019) proposes a consignment-based coordination approach between a consignor (supplier) and a consignee (retailer). This paper further advances that framework by incorporating a key decision component into the coordination policy. This addition fosters a more equitable setting between business partners and makes a significant improvement over the original model.

The rest of the paper is organized as follows: The next section reviews relevant studies on incentive-aligned supply contracts, followed by research questions and methodology in section 3. Following this, the paper develops normative models for supply contracts using the newsvendor approach, in which both the base case and the consignment sales – vendor-managed inventory (CS-VMI) contract are analyzed. Section 5 presents sensitivity analysis and stress testing through simulation experiments, accompanied by a detailed discussion of practical implications and managerial insights. The final section outlines the conclusions, acknowledges the study's limitations, and suggests directions for future research.

2 Literature review

2.1 Supply chain coordination

Over the past few decades, companies have witnessed healthy relationships grow from supply chain collaborative initiatives based on the proper alignment of incentives and efforts among business partners (Fleidner 2003). Walmart and P&G implemented the Collaborative Planning, Forecasting, and Replenishment (CPFR) initiative in the mid- 1990 s based on their continuous replenishment (CR) program (Han and Dong 2015). The main driving factor behind this movement was the exponential growth in information infrastructure and technology, highlighting the need to achieve supply chain transparency and coordination at strategic as well as operational levels (Zhao et al. 2017; Datta and Christopher 2011; Kim and Mahoney 2010).

In a multi-echelon decentralized system with information asymmetry, each party seeks to optimize its own operations, typically leading to the double-marginalization problem and undermining supply chain performance (Spengler 1950; Ghili and Schmitt 2023). Understanding the need for collaborative and integrative approaches to decision-making in such a setting, numerous papers propose measures to remedy the double-marginalization scenario and to design incentive-aligned contracts agreeable to stakeholders in the multi-stage supply chain (Grubic et al. 2010; Png and Wang 2010; Lee and Rosenblatt 1986; Jeuland and Shugan 1983). The core of this coordination lies in its capacity to facilitate risk-hedging and risk-sharing while enhancing overall system performance (Bahinipati et al. 2009). Examples of supply contracts based on well-designed incentives include buy-back contracts (Yao et al. 2008; Pasternack 1985), revenue-sharing contracts (Qin and Yang 2008; Cachon and Lariviere 2005; Giannoccaro and Pontrandolfo 2004), integrated inventory replenishment (Glock 2012; Banerjee 1986), price-discount contracts (Cachon 2004; Bernstein and Federgruen 2005), consignment sales contracts (Zahran et al. 2016), and vendor-managed inventory (Hu et al. 2018; Yao et al. 2007).

The newsvendor model is a widely used approach for addressing challenges in supply chain coordination associated with products with limited shelf life. Prior studies have employed this approach to explore how incentive structures can be designed to yield mutually beneficial contracts among collaborating parties dealing with short shelf-life products (Mohammadivojdan et al. 2022; Sarkar et al. 2018; Prasad et al. 2011). Building on the recognized need for collaboration when serving risk-averse retailers, this paper assesses the effectiveness of a vendor-initiated coordination policy for such products with the newsvendor framework.

The study of supply contracts has progressively evolved to emphasize long-term value creation that integrates both economic objectives and socio-environmental considerations. De Zegher et al. (2019) investigate how contract design influences the adoption of technological innovations in agricultural value chains, particularly when benefits and costs are not evenly distributed. Their work highlights the potential for supply contracts to foster creating shared value (CSV) by aligning economic incentives with social goals.

Similarly, Zhang et al. (2023), using a game-theoretic model, demonstrate that CSV can be achieved in contract farming through long-term partnerships and investment commitment from farmers when incentives are properly aligned. Supporting this perspective, Chen et al. (2023) present a case study of a Chinese agricultural firm, illustrating how innovations in supply chain finance can serve as a lever for CSV by making sustainable sourcing financially viable and building trust-based long-term relationships. At a more strategic level, Visser and Kymal (2015) extend this idea by proposing integrated value creation (IVC), an evolution of corporate social responsibility (CSR) and CSV. IVC adopts a holistic integration approach, encouraging companies to view supply contract design and partner relationships as integral to a broader value creation framework that aligns governance and supply chain management with social value creation.

2.2 Vendor-managed inventory

A vendor-managed inventory (VMI) contract incorporates continuous replenishment (CR) and information visibility with the strategic goal of strengthening relationships between business partners (Yao and Dresner 2008). In a VMI setting, the vendor (or the manufacturer) takes full responsibility for replenishment and inventory decisions at its buyers in a fully transparent and coordinated manner, whereas the buyer (or the retailer) makes demand and inventory information available to the vendor (Darwish and Odah 2010; Angulo et al. 2004).

In such a contract, buyers (retailers) generally benefit from improved service levels and transportation efficiencies with lower cycle stocks (Waller et al. 1999) as the vendor is capable of making the accurate replenishment decision under information symmetry. In a typical setting, the vendor has the upstream perspective to make more informed inventory decisions for the overall system, granted that the demand is readily accessible to the vendor, as exemplified in most VMI implementation cases such as Walmart and P&G partnerships, Boeing and Alcoa, and Campbell Soup and its retailers (Yao et al. 2007; Micheau 2005; Waller et al. 1999; Cachon and Fisher 1997). On the other hand, numerous examples of supply chain coordination failures (e.g., Target Canada's supply chain disaster in 2015, Boeing 787 Dreamliner delays in 2011, etc.) originate from a lack of trust, incomplete information sharing, or inequitable benefits allocated between supply chain partners (Paul 2018; Megits and Schuster 2015). Although there are cases reported on the disparity in the allocation of benefits from VMI partnerships in favour of the buyer (Ellegaard and Freytag 2010; Mukhopadhyay and Kekre 2002), others also show that the vendor tends to benefit in the long run (Dong and Xu 2002) or under high inventory holding costs (Ru et al. 2018).

It is noted, however, that for perishables or relatively newer products (e.g., hi-technology products or high fashion goods) with short selling seasons, the buyer may be reluctant to make financial commitments as the demand is largely unpredictable. This uncertainty renders traditional supply contracts, such as wholesale price contracts or VMI riskier and less appealing (Son 2019). In such settings, characterized by product novelty and limited selling windows, the incentive for business partners to establish cooperative relationships is notably stronger (Mesa and Galdeano-Gomez 2015). Under a similar context, Choi (2018) addresses the challenge of coordination and proposes a contract to achieve two-level coordination in a highly volatile fashion supply chain.

2.3 Consignment Sales (CS) contracts

In a related vendor-initiated replenishment model known as the consignment sales (CS) contract, the consignee pays the consignor only after the sales of the goods to the end customer. Ownership remains with the consignor throughout the process and transfers directly to the end customer upon sale, shifting most financial risk from the consignee to the consignor. The consignee remits the sales proceeds to the consignor, less a commission, and returns any unsold inventory to the consignor at the end of the selling season. Sarkar (2014) provides a comprehensive review of research on various CS models and classifies them based on system configurations, cost and profit measurements, and operational policies. In one of the earlier papers on CS, Braglia and Zavanella (2003) model CS and inventory contracts and prove its dominance in a stochastic environment over the standard joint economic lot size (JELS) model. Their paper is followed by an industry case study on a components manufacturer for the automotive industry, in which potential benefits and pitfalls are discussed (Valentini and Zavanella 2003). Other applications of CS and inventory contracts include business scenarios in which two retailers are allowed to return shared inventory in the medical supply chain (Zhang et al. 2022), the demand at the buyer is stock-dependent (Zanoni and Jaber 2015), and channel participants coordinate using the CS model and a revenue sharing scheme (Chen et al. 2010; Wang et al. 2004). In particular, studies of CS contracts along with a revenue-sharing agreement largely show a robust incentive arrangement using the Stackelberg game approach, allowing both the manufacturer and the retailer to be better off (Chernonog 2021; Buratto et al. 2019; Lim et al. 2015). New products with minimal sales history or products with limited shelf life are deemed a good fit for CS contracts from the retailers' perspective because they bear little financial risk for the products carried on consignment.

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In a conventional CS contract, the consignee (i.e., retailer) makes decisions on the consigned quantity and order frequency, whereas the consignor (i.e., manufacturer) commands the ownership of the inventory stored at the consignee and bears the responsibility for the significant portion of inventory holding costs (Ben-Daya et al. 2013; Gümüs et al. 2008). Further, although the commission rate can be jointly decided, the consignee typically selects the commission rate for the CS contract (Zhang et al. 2010). As such, with the consignee being virtually free of any financial commitments, the consignor is often left in a vulnerable position. In a seminal work in marketing literature related to the CS contract, Pasternack (1985) proposes the return (or buy-back) policy for perishable commodities and proves the optimality of the return policy in a multi-retailer setting when unlimited returns are allowed at partial credits. Here, the wholesale price and the partial credit value are negotiated between the vendor and the retailer as part of the return contract.

As for the research on inventory ownership and decisions, Xu et al. (2016) study the effects of inventory ownership under various business scenarios when CS contracts are used. In another comparative study of different consignment arrangements, Ru and Wang (2010) examine retailer-managed consignment inventory (RMCI) and vendor-managed consignment inventory (VMCI) to reveal that delegating the inventory decision to the vendor benefits both parties. Other studies on CS contracts explore the impact of consumer behaviour related to non-defective returns under RMCI and VMCI framework (Bieniek 2021; Hu et al. 2014) and propose diverse strategies for leveraging CS contracts to advance environmental sustainability goals (Tat et al. 2023; Masanta and Giri 2022).

2.4 Consignment sales – vendor-managed-inventory (CS-VMI) contracts

This paper proposes an agreement between supply chain partners that combines elements of CS and VMI contracts, referred to as a CS-VMI contract, where the consignor determines both the commission rate and the consigned quantity to be delivered to the consignee (Zahran et al. 2016), in contrast to the conventional CS contracts discussed earlier. Thus, the relationship between the stakeholders in the CS-VMI contract becomes more equitable than traditional CS contracts as the consignor now makes decisions regarding the quantity and the commission rate to ensure the contract is financially appealing for the consignee to engage in the agreement. While simultaneously considering both VMI and CS contracts may complicate decision-making and inventory ownership across different stages of the process, it also presents greater opportunities for enhancing coordination (Braglia et al. 2014; Ben-Daya et al. 2013). Existing studies related to CS-VMI examine the contract using the joint-economic lot sizing (JELS) idea (Zanoni and Jaber 2015), with imperfect manufacturing processes (Bazan et al. 2014), with proportional stockout penalties (Lee and Cho 2014), and with stock- and price-dependent demand (Hemmati et al. 2017). Others consider cooperative advertising efforts between operations and marketing (De Giovanni et al. 2019) and the fairness of profit allocation between the retailer and the vendor (Hu et al. 2018) when CS-VMI is in place.

As noted in Section 1, this paper extends and advances the framework proposed in Son (2019) by designing CS-VMI, a more balanced and equitable coordination mechanism that reinforces the consignor's role in contract negotiations. In this paper, the consignor determines both the consigned quantity and the commission rate, marking a significant shift from Son (2019), which relied on the product's salvage value as the key policy parameter in assessing the effectiveness of the consignment contract. With the return of the unsold inventory to the consignor embedded in the CS contract, however, the salvage carries little weight in determining the effectiveness of the contract. By proposing an incentive-aligned CS-VMI contract for limited shelf-life products using the newsvendor model, this paper addresses the research gap in vendor-initiated collaboration. To date, the newsvendor approach has rarely been applied to the CS-VMI approach. Table 1 summarizes the existing literature on the significance of supply chain coordination and consignment-based contracts and highlights how this study builds upon and contributes to the current body of research on consignment-based supply agreements.

As the need for effective coordination mechanisms for limited shelf-life products continues to grow, the CS-VMI contract offers a promising approach to addressing the research gap in identifying contractual structures that ensure equitable outcomes for all stakeholders. Table 2 expands on Ben-Daya et al. (2013) and Gümüs et al. (2008), detailing the allocation of decision rights and cost responsibilities across CS-VMI and other related supply contracts.

3 Research questions and methodology

This paper investigates the effectiveness of the CS-VMI contract between the consignor (manufacturer) and the consignee (retailer). To achieve this, the study adopts the newsvendor framework to analyze the operational characteristics of the coordinated policy using a normative model and conducts a comprehensive simulation-based sensitivity analysis to demonstrate how supply chain performance can improve through the CS-VMI contract. In the sensitivity analysis, the paper conducts a set of stress tests to identify hidden vulnerabilities in the system by expanding the scope of parameter values to incorporate the disruptive natures

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Table 1 Summary of literature on consignment-based contracts

Research stream	Source	Main focus and contribution
Supply contracts & creating shared value (CSV)	Zhang et al. (2023); Chen et al. (2023); de Zegher et al. (2019); Visser & Kymal (2015)	Significance of trust-based long-term partnerships; alignment of economic goals and social-environmental considerations.
Short product life cycles & time-based competition	Shen et al. (2019); Olhager (2013); Wu et al. (2012); Beamon (2008); Jacobs and Weston (2007)	Challenges of managing limited life-cycle products; the importance of time-based competition in the global supply chain.
Supply chain resilience & disruptive risks	Salama and McGarvey (2023); Kazancoglu et al. (2022); Durach et al. (2020)	Need for supply chain resilience in light of global disruptions, e.g., COVID- 19 pandemic; stakeholder engagement in multi-tiered supply chains.
Supply chain competitiveness based on collaboration	Gaultier and Marcello (2021); Tang et al. (2018); Zhao et al. (2017); Mesa and Galdeano-Gomez (2015)	Emphasis on collaboration, buyer-supplier relationships; competitiveness through supply chain agility and alignment.
Supply chain coordination & incentive-aligned contracts	Ghili and Schmitt (2023); Son and Enstroem (2021); Han and Dong (2015); Glock (2012); Qin and Yang (2008); Yao et al. (2008); Cachon (2004); Giannoccaro and Pontrandolfo (2004); Fleidner (2003); Pasternack (1985); Spengler (1950)	Development of incentive-aligned contracts to address double marginalization and improve coordination; different types of supply contracts and their effectiveness in aligning stakeholders' interests in the supply chain.
Vendor-managed inventory (VMI)	Darwish and Odah (2010); Yao and Dresner (2008); Yao et al. (2007); Dong and Xu (2002); Waller et al. (1999);	Structure and benefits of VMI contracts; improved replenishment through information sharing; challenges related to trust and benefit distribution.
Consignment sales (CS) contracts	Zhang et al. (2022); Chernonog (2021); Son (2019); Sarkar (2014); Braglia and Zavanella (2003); Zanoni and Jaber (2015); Chen at al. (2010)	Design and analysis of CS contracts; need for risk hedging between business partners; inventory ownership, and joint decision-making challenges.
Consignment sales – VMI (CS-VMI)	Hu et al. (2018); Hemmati et al. (2017); Zahran et al. (2016); Braglia et al. (2014); Ben-Daya et al. (2013); Gümüs et al. (2008)	A hybrid model combining CS and VMI; focus on equitable stakeholder participation and consignment decision-making.
The present study (CS-VMI)		Expansion of the CS-VMI model under perishability and risk aversion; Vendor-initiated contract with improved risk-benefit balance.

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Table 2 Decisions and ownership under different supply contracts

	Order Quantity	Inventory ownership	Cost of capital	Commission rate	Return of overstock
RMI*	Retailer	Retailer	Retailer		No
VMI	Vendor	Retailer	Retailer		No
CS	Retailer	Vendor	Vendor	Joint or retailer	Yes
Buy-back	Retailer	Retailer	Retailer		Yes
CS-VMI	Vendor	Vendor	Vendor	Vendor	Yes

*Retailer-managed inventory

(e.g., added volatility and complexity) of the global supply network characterized by the growing geopolitical risks, protectionism, and the pandemic.

The research develops an incentive-aligned contract and evaluates its performance relative to the traditional retailer-managed inventory (RMI) ordering. Using RMI as the baseline, the study explores the internal dynamics of the supply chain and examines how the additional benefits generated under the CS-VMI model can be distributed between the consignor and the consignee. The paper addresses the following research questions:

- How does CS-VMI compare to traditional RMI in terms of effectiveness as a collaborative initiative for limited shelf-life products?
- How do policy parameters (e.g., commission rate and retail price) and structural parameters (e.g., demand variability and customer loyalty) affect the performance of CS-VMI?
- Under what conditions can the CS-VMI contract enhance supply chain profitability and service levels for all parties, both locally and globally?

4 CS-VMI contract in a two-echelon supply chain

The relationship between the vendor and the retailer in a typical CS agreement can be characterized as a principal-agent relationship (Corbett 2001), where the retailer (consignee) operates as an agent on behalf of the manufacturer (consignor), without taking legal ownership of the product. This arrangement allows the retailer to mitigate financial risks associated with the purchase, storage, or overstocking of the product. Under the CS contract, the consignee remits the sales proceeds to the consignor, less the commission fee. Further, since the contract permits the return of unsold inventory to the consignor, the consignee is now incentivized to maintain a large stock as a buffer against demand uncertainty. The consignor, on the other hand, may face working capital shortages if the payments are delayed due to slow sales at the consignee (Williams 2000). This highlights the need for properly aligned incentives to ensure an equitable distribution of risks and rewards between business partners, a critical element lacking in traditional consignment-based contracts.

The CS-VMI contract proposed in this paper ensures that the consignor will not be stranded in a vulnerable position. With the consignor setting up the commission rate that guarantees an equitable contract, both the consignor and the consignee would be better off financially than in the base case (i.e., RMI system). Once the consigned quantity is determined by the consignor to optimize the CS-VMI contract, the ideal level of commission rate will be applied to identify a proper profit-sharing mechanism between the two parties. The process associated with the CS-VMI contract is summarized in Fig. 1.

4.1 Base case

Using the traditional newsvendor framework, the base case addresses the inventory stocking problem for a short shelf-life product. In this setup, the retailer independently determines the order quantity prior to the selling season, and the manufacturer fulfils the order accordingly. As with a typical decentralized supply chain, there is no coordination between the retailer and the manufacturer in the base case, nor is there a buy-back agreement for unsold items at the end of the selling season.

When making stocking decisions for seasonal or new products, the retailer exercises caution in inventory investments, factoring in the risks associated with short shelf-life or potential overstocking. In essence, the retailer's order quantity under the base case RMI model is driven by its target service level. In contrast, the vendor typically prefers to maximize product availability in the market. The following notations are introduced to model the base case scenario using the newsvendor approach:

p — unit retail price

w — unit wholesale price paid by the retailer to the manufacturer

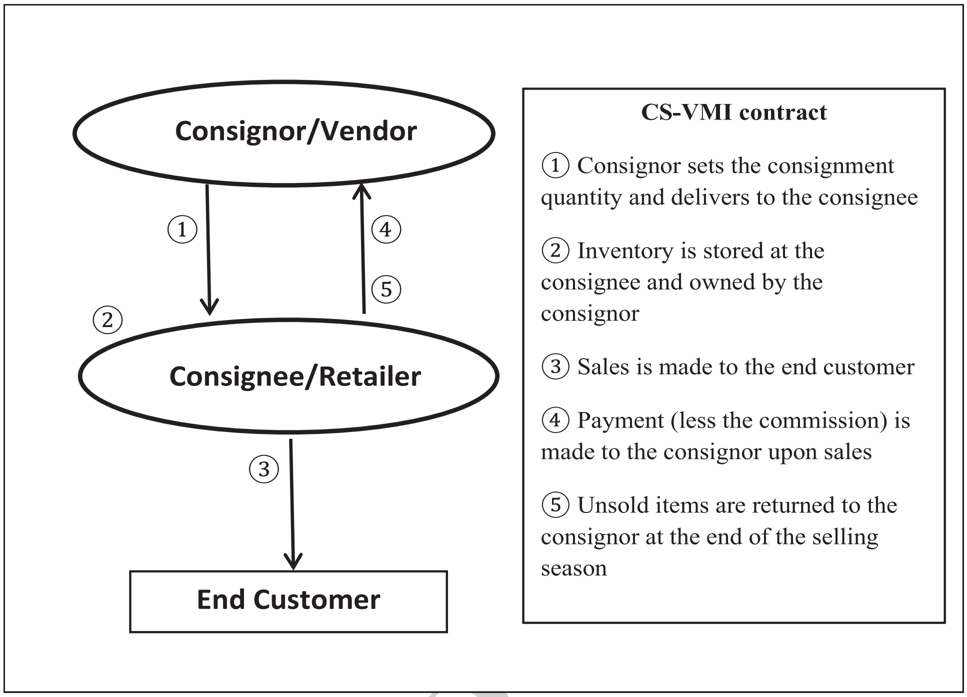

Fig. 1 Consignment sales – vendor-managed inventory (CS-VMI) contract

s unit salvage value

$gw(R)$ unit loss of goodwill penalty incurred at the retailer

SL service level for the retailer

Q order quantity placed by the retailer at the beginning of the selling season

The understocking (C_U) and overstocking costs (C_O) at the retailer along with the service level for the base case (BC) are summarized in equations (1) through (3):

$$C_U(BC) = p - w + gw(R) \tag{1}$$

$$C_O(BC) = w - s \tag{2}$$

$$SL(BC) = [p - w + gw(R)]/[p - s + gw(R)] \tag{3}$$

In the traditional newsvendor setting, the manufacturer's profitability is solely determined by the retailer's stocking decision (Q), which is often lower than the ideal level for the manufacturer (or for the whole system). This is because the retailer's desired service level is constrained by the risk of overstocking and associated penalties at the end of the selling season.

4.2 Consignment sales – vendor-managed inventory (CS-VMI) contract

Under the traditional CS contract, where the consignee determines the consignment quantity and has the option to return unsold inventory (Table 2), the consignee is incentivized to order large quantities, avoiding any overstocking risk. Conversely, the consignor has its own optimal consignment quantity, likely lower than the consignee's preference, based on the assessment of the trade-off between understocking (C_U) and overstocking (C_O) costs. In such a setting, designing a CS agreement that is both incentive-aligned and equitable for all parties cannot be guaranteed.

In contrast, under the CS-VMI contract proposed in this paper, the consignor is tasked with determining both the consigned quantity and the commission rate. This structure aims to ensure not only superior profitability compared to the base case but also an equitable contract for both parties. Ideally, the outcome is a consignment quantity that maximizes the overall supply chain profit.

The following additional notations are introduced to model the CS-VMI scenario:

c unit manufacturing cost

$gw(R)$ unit loss of goodwill penalty incurred at the consignee (retailer)

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$gw(M)$	unit loss of goodwill penalty incurred at the consignor (manufacturer)
r	commission rate, where $p{\cdot}r$ is the unit commission paid to the consignee
Q	consigned quantity owned by the consignor but stored at the consignee
x	market demand normally distributed with an average μ and a standard deviation σ

A traditional newsvendor problem typically assumes that the retailer faces normally distributed market demand (Silver et al. 1998). This assumption is similarly adopted in the CS literature, including studies by Battini et al. (2010) and Hu et al. (2018). The analysis of the CS-VMI contract below follows the approach used in Son (2019). In this setup, the consignor and the consignee incur understocking (C_U) and overstocking (C_O) costs, respectively, as shown in equations (4) through (7), assuming that unsold items at the end of the season are returned to the consignor:

Consignee (Retailer):

$$C_U(R) = p \cdot r + gw(R) \tag{4}$$

$$C_O(R) = 0 \tag{5}$$

Consignor (Manufacturer):

$$C_U(M) = p \cdot (1 - r) - c + gw(M) \tag{6}$$

$$C_O(M) = c - s \tag{7}$$

Applying the standard newsvendor result, the expected profit at the consignee, $EP_R(Q)$, is obtained as in (8):

If demand $x \le Q$, consignee profit $= x \cdot pr$

If demand $x > Q$, consignee profit $= Q \cdot pr - gw(R)(x - Q)$

$$\begin{aligned} EP_R(Q) = \int_0^Q x \cdot pr \cdot f(x)dx + \int_Q^\infty \\ \left[Q \cdot pr - gw(R) \cdot (x - Q)\right] \cdot f(x)dx \\ = pr \cdot \mu - E(s)[pr + gw(R)] \end{aligned} \tag{8}$$

where $f(x)$ is the density function of demand x and $E(s)$ is the expected shortage amount.

From equation (8), it follows that $\frac{dEP_R(Q)}{dQ} = -\left[pr + gw(R)\right] \cdot (SL(R) - 1) = 0$, which implies that the consignee's ideal service level under the CS-VMI contract is 100%. In other words, regardless of the commission rate, the consignee has the incentive to stock as much as possible at the start of the selling season to eliminate any risk of understocking, effectively transferring the entire overstocking risk to the consignor.

The consignor, on the other hand, can explore a few options here: The first option is to identify the consignment sales contract that is *locally optimized for the consignor itself*. This approach yields a service level higher than that of the base case (as given in equation (3)) and results in increased profits for both parties. Using the consignor's understocking and overstocking costs derived in equations (6) and (7), the consignor's optimal service level and corresponding commission rate are determined by equations (9) and (10).

$$SL(M) = [p(1 - r) - c + gw(M)]/[p(1 - r) - s + gw(M)] \tag{9}$$

$$r = \frac{p - s + gw(M)}{p} - \frac{(c - s)}{p(1 - SL)} \tag{10}$$

As long as the commission rate optimized for the consignor in (10) remains financially appealing to the consignee, both parties will achieve higher profits than the base case, although the outcome may still fall short of maximizing the total supply chain profit.

The second option for the consignor is to determine the service level and commission rate *optimized for the overall supply chain*. In this context, the commission rate in the CS-VMI contract serves as a mechanism to allocate the additional profits generated in a manner that is mutually acceptable to both parties. By maximizing total supply chain profit under CS-VMI, each stakeholder seeks a commission rate that ensures an equitable distribution of the gains. From a system perspective, achieving optimality is contingent not only on the consignment quantity but also on the commission rate applied to the retail price. The understocking and overstocking costs for the entire system under CS-VMI are defined in equations (11) and (12).

$$C_U(S) = p - c + g \tag{11}$$

$$C_O(S) = c - s \tag{12}$$

where $g = gw(R) + gw(M)$

The expected profit for the overall system, $EP_S(Q)$, can be expressed as in (13)

$$EP_S(Q) = (p - s)\mu - (c - s)Q - (p - s + g)\sigma \cdot E(z) \tag{13}$$

with the service level and the optimal commission rate determined as shown in (14) and (15).

$$SL(S) = (p - c + g)/(p - s + g) \tag{14}$$

$$r = 1 - \frac{c - s}{p(1 - SL)} - \frac{s - g}{p} \tag{15}$$

The optimal commission rate for CS-VMI, as defined in equation (15), is expected to ensure a mutually agreeable balance of risk and reward between the consignor and the consignee.

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5 Numerical experiments and managerial insights

5.1 Designing experimental settings

The numerical experiments in this study explore a range of business scenarios by varying key parameters such as demand variability, loss of goodwill penalty at each party, and retail price. The analysis investigates how these structural and policy parameters influence overall system performance and help determine the desired commission rate for the CS-VMI contract. Sensitivity analysis is conducted to gain insights into the interactions among different parameters and to isolate the impact of each parameter. Performance is evaluated based on the percentage improvement in supply chain profitability and service level gains relative to the base case. Table 3 outlines the parameter values and assumptions used in the numerical experiments and sensitivity analysis.

The market demand is modelled with an average of 1,000 units over the selling season, with the demand variability represented by the coefficient of variation (cv) of demand set at 0.1 (low variability), 0.3 (medium variability), and 0.5 (high variability). This setup aligns with assumptions in similar CS-VMI studies (Hu et al. 2018; Battini et al. 2010). For instance, Hu et al. (2018) assume normally distributed market demand with a mean of 1,000 units and a variance of 200 units. Also, to assess the effects of *brand loyalty to the manufacturer* and *customer loyalty to the retailer*, the loss of goodwill penalties at the consignor, $gw(M)$, and consignee, $gw(R)$, are varied. Finally, retail markups of 33%, 67%, and 100% are tested to assess their impact on expected system profit, service level, consignment quantity, and commission rate. In total, 81 business scenarios (= 3 x 3 x 3 x 3) are analyzed in the numerical experiments, as summarized in Table 3.

For each scenario, simulation runs are conducted over 500 cycles with 3,000 replications to ensure that the results accurately represent typical CS-VMI contract behavior under varying conditions. In addition to the 81 business scenarios, a set of 27 extreme scenarios designed to simulate disruptive events are investigated through simulation-based stress testing.

5.2 Discussion of results from numerical experiments

5.2.1 Impact on supply chain profit and service levels

The CS-VMI contract leads to a considerable increase in total supply chain profit, defined as the combined profit of the consignor and consignee, compared to the traditional RMI policy used in the base case. In this proposed CS-VMI contract, the consignor selects the optimal consigned quantity and commission rate to ensure the consignee earns higher profit than the base case scenario, offering a strong financial incentive for participation. Since the consignee prefers to hold a substantially larger inventory under CS-VMI, the consignor can maintain a service level close to its optimal service level, $SL(M)$, as defined in equation (9), by supplying more quantity than the traditional newsvendor model would suggest.

Moreover, supply chain profitability can be further enhanced by choosing the consigned quantity that corresponds to the optimal service level for the entire supply chain, $SL(S)$, as given in equation (14). By fairly distributing the additional gains generated through CS-VMI, both the consignor and consignee benefit financially in comparison to the RMI-based policy. As illustrated in Fig. 2 and Fig. 3, the percentage increase in the system profit over the base case (Fig. 2) aligns with the corresponding improvement in service level (Fig. 3), demonstrating the effectiveness of the CS-VMI approach.

Fig. 2 and Fig. 3 reveal that when the retailer's goodwill loss penalty is relatively low (e.g., $gw(R)$ = \$20), the target service level under the RMI ordering policy is markedly reduced. This suggests greater potential for improving both

Table 3 Parameters and assumptions for simulation experiments

Fixed parameters (per unit)	Parameters (range)
w = \$30 (wholesale price)	cv = 0.1, 0.3, and 0.5
c = \$20 (manufacturing cost)	*Retail markup* = 33%, 67%, and 100%
s = \$15 (salvage value)	$gw(M)$= \$20, \$35, and \$50 (per unit)
	$gw(R)$= \$20, \$35, and \$50 (per unit)
	$g = gw(R) + gw(M)$
To be determined	**Assumptions**
r = between 0 and 1 (commission rate)	μ= 1,000; σ = as per cv Demand follows a Normal distribution ~ N (μ, σ)
Q = as per service level	Unsold items at the consignee are returned to the consignor at the end of the selling season.

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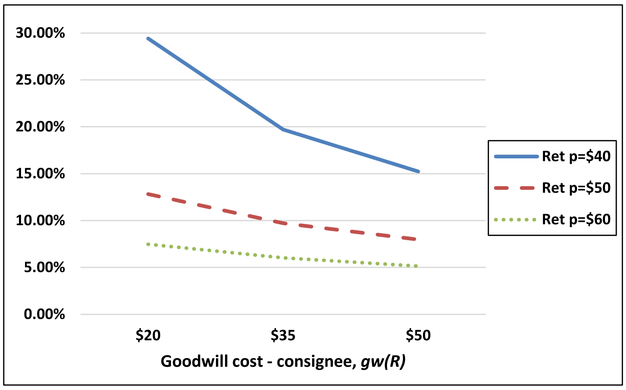

Fig. 2 Percentage improvement in profit over the base case ($cv = 0.3$, $gw(M) = \$50$)

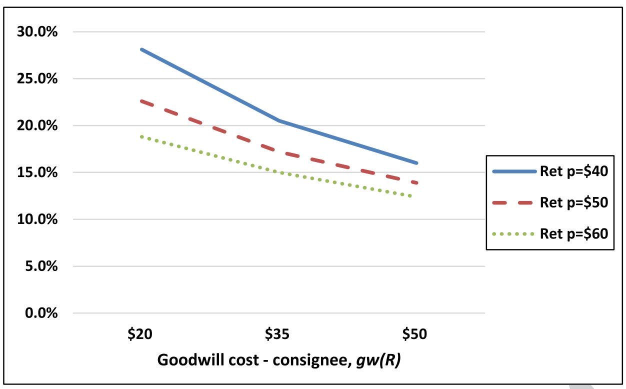

Fig. 3 Improvement in the service level over the base case ($cv = 0.3$, $gw(M) = \$50$)

supply chain profit and service level through the adoption of the CS-VMI arrangement.

In the same context, a relatively low retail price, p (e.g., p=\$40) under the RMI ordering (or the base case) results in a reduced target service level for the retailer, again implying greater potential for an increase in the service level and profitability by implementing the CS-VMI contract.

5.2.2 Customer loyalty vs. brand loyalty

Customer attitudes toward a brand or retailer can influence purchasing behavior, particularly for products with limited shelf-life, where the sales window is narrow. In the marketing literature, customer loyalty is defined as a customer's preference to repurchase a product despite external efforts to encourage switching (Oliver 1999; Dick and Basu 1994). On the contrary, brand loyalty reflects a deeper and more enduring commitment rooted in positive emotional attachment to a specific brand (Kotler and Keller 2016; Mellens et al. 1996). Within the framework of the newsvendor problem, customer loyalty is associated with the loss of goodwill penalty at the consignee (retailer), while brand loyalty corresponds to the loss of goodwill at the consignor (manufacturer). A higher loss of goodwill penalty at the consignee implies lower customer loyalty and a stronger likelihood of customer switching. Similarly, a higher loss of goodwill penalty at the consignor suggests reduced brand loyalty.

In all cases examined, total supply chain profit declines as the loss of goodwill penalty increases for either party. The higher the consignee's loss of goodwill penalty (i.e., low customer loyalty), the lower the supply chain profit. The same holds true for higher goodwill loss at the consignor, which reflects weaker brand loyalty. However, the effect of these loyalty factors on the percentage improvement in supply chain profit under the CS-VMI contract yields differing insights. The percentage gain in profitability compared to the base case (RMI policy) increases with stronger customer loyalty but decreases as brand loyalty strengthens. This suggests that lower brand loyalty (or higher $gw(M)$) has minimal effect on service levels in the base case but leads to a notably higher target service level under CS-VMI. Fig. 4 further illustrates the joint effect of customer loyalty and brand loyalty on the percentage improvement in supply chain profit under CS-VMI, showing a range of gains from 8.82% to 29.42% compared to the base case.

Regarding service level improvements, customer loyalty has a more significant impact than brand loyalty when the CS-VMI contract is used. As shown in Fig. 5, higher customer loyalty (e.g., $gw(R)$=\$20) leads to greater potential for enhancing the overall system service level. In contrast, variations in brand loyalty, expressed as the consignor's loss of goodwill penalty, have a less noticeable effect on service level improvements within the CS-VMI framework. This implies that the manufacturer (i.e., the consignor) is less motivated to increase consigned inventory levels when brand loyalty is relatively low. Under the traditional RMI setting, the retailer's loss of goodwill penalty, $gw(R)$, is a primary driver of both service level and stocking decisions.

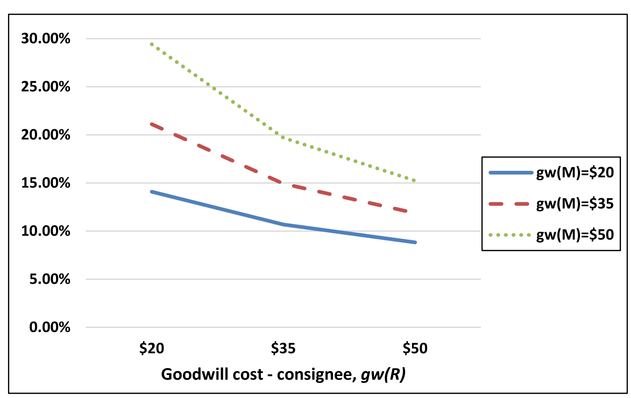

Fig. 4 Impact of the loyalty factors on percentage improvement in profit ($cv = 0.3$, $p = \$40$)

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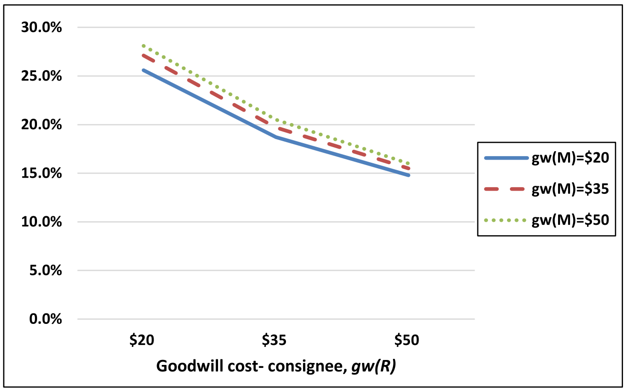

Fig. 5 Impact of loyalty factors on improvement in service level ($cv = 0.3$, $p = \$40$)

In the CS-VMI case, however, both the consignor's and consignee's loss of goodwill penalties influence the target stocking quantity corresponding to the desired system-wide service level. That is, lower brand loyalty (e.g., $gw(M) = \$50$) results in greater potential for service level improvement under CS-VMI.

In summary, as shown in Fig. 5, service level improvements over the base case tend to increase with customer loyalty but decrease with stronger brand loyalty. This trend aligns with the observed effects on percentage improvements in supply chain profit, as observed in Fig. 4. The sensitivity analysis on customer loyalty and brand loyalty highlights the need for a deeper investigation of their isolated and joint impacts on supply chain profitability, offering valuable managerial insights. Table 4 presents the expected profit for each party as well as the entire supply chain under the CS-VMI contract. While a higher loss of goodwill penalty at each party, whether at the consignor or consignee, individually reduces total supply chain profit, their joint impact on the additional profit distribution under the CS-VMI contract reveals an important insight. Specifically, for a fixed level of brand loyalty, the consignor stands to gain more when the consignee faces a relatively high loss of goodwill penalty (or when customer loyalty diminishes), as shown in Table 4.

A similar pattern is observed with respect to the consignee's financial gains. The consignee's profit increases as the consignor's loss of goodwill penalty rises (or as brand loyalty declines for a given level of customer loyalty). In essence, this suggests that under the CS-VMI arrangement, each party benefits more financially when the other party faces declining loyalty, whether it be lower customer loyalty or reduced brand loyalty.

5.2.3 Impact of demand variability

For products with limited shelf-life, overall supply chain profit generally rises with increasing retail prices across all

AQ2 **Table 4** Impact of customer loyalty vs. brand loyalty on supply chain profit

cv = 0.3, p=$40			
GW(M)=$20	GW-ret		
CS-VMI	$20	$35	$50
Exp prof - consignee	$5,809	$4,736	$4,029
Exp prof - consignor	$11,379	$12,317	$12,903
Exp prof - SC	$17,188	$17,053	$16,932
% Improve over base case	14.09%	10.68%	8.82%

cv = 0.3, p=$40			
GW(M)=$35	GW-ret		
CS-VMI	$20	$35	$50
Exp prof - consignee	$6,167	$4,919	$4,140
Exp prof - consignor	$10,879	$12,018	$12,704
Exp prof - SC	$17,046	$16,937	$16,844
% Improve over base case	21.10%	14.93%	11.87%

cv = 0.3, p=$40			
GW(M)=$50	GW-ret		
CS-VMI	$20	$35	$50
Exp prof - consignee	$6,593	$5,126	$4,266
Exp prof - consignor	$10,347	$11,721	$12,502
Exp prof - SC	$16,940	$16,847	$16,768
% Improve over base case	29.42%	19.71%	15.23%

scenarios, regardless of the presence of the CS-VMI contract (Fig. 6). However, as observed in Fig. 7, the CS-VMI contract yields greater profit improvement in scenarios involving lower retail prices.

A similar trend is observed regarding demand variability, measured by the coefficient of variation (cv). Lower variability (e.g., cv= 0.1) leads to higher overall supply chain profit (Fig. 6), while higher variability (e.g., cv= 0.5) results in a much larger percentage improvement in profit when CS-VMI is implemented (Fig. 7). Among all scenarios, the largest percentage gain (nearly 75%) occurs when both the retail price is low (p=\$40) and the demand is highly volatile (cv= 0.5). This highlights that CS-VMI has the greatest potential for boosting profitability under challenging conditions, such as low retail prices, high volatility, or both.

Using the same parameters as in Fig. 6 and 7, the numerical experiments demonstrate how the additional profits generated under CS-VMI can be optimally allocated between the parties based on the established commission rate. As shown in Fig. 8, the commission rate increases steadily with retail price but declines as demand variability (cv) rises. While the commission rate in CS-VMI is essential in ensuring fair profit-sharing and achieving supply chain coordination, it is independent of the total supply chain profit. Instead, it is derived from the system's optimal service level, as defined in equations (14) and (15), ensuring that both parties benefit financially. To maintain equity, this paper proposes that the ratio of the consignee's profit to the consignor's profit remains unchanged before and after the distribution of the additional profits accrued from the CS-VMI contract.

In scenarios where the consignor faces a high loss of goodwill penalty or exhibits low brand loyalty (e.g., $gw(M)$ = \$50) as in Fig.8, the consignor is naturally more motivated to offer a higher commission rate to make the CS-VMI contract appealing to the consignee, especially when the retail price is high (p=\$60).

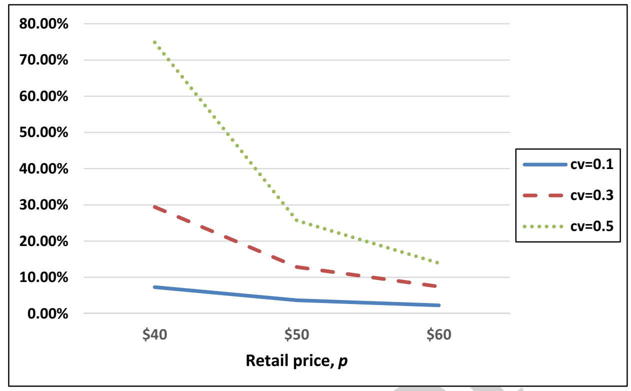

Fig. 7 Percentage improvement in profit over the base case ($gw(R)$ = \$20, $gw(M)$ = \$50)

5.2.4 Stress-testing the CS-VMI contract

The relevance of any supply contract lies in its ability to withstand extreme disruptive conditions. Events like the COVID- 19 pandemic and geopolitical conflicts have caused widespread inventory delays and shortages, triggering unexpected spikes in procurement costs throughout the supply chain. While the sensitivity analysis assumes fixed parameter values for manufacturing cost (c=\$20) and wholesale price (w=\$30), a stress test is essential to identify hidden vulnerabilities and assess a company's potential resilience under adversarial conditions.

To this end, a number of business scenarios are examined to evaluate the effectiveness of the CS-VMI contract as a risk-mitigation measure when procurement costs surge due to disruptive events, resulting in significant increases in both manufacturing cost (e.g., up to c=\$40) and wholesale price. Notably, the retailer's inclination to engage in the CS-VMI contract under such conditions is reflected in the desired commission rate, which decreases monotonically with rising wholesale price (w) as illustrated in Fig. 9.

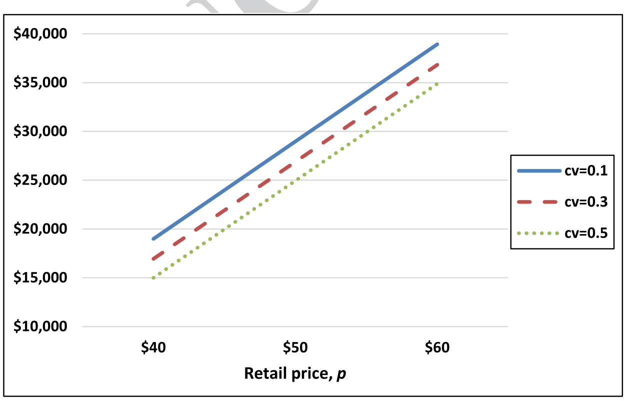

Fig. 6 Supply chain profit with the CS-VMI contract ($gw(R)$ = \$20, $gw(M)$ = \$50)

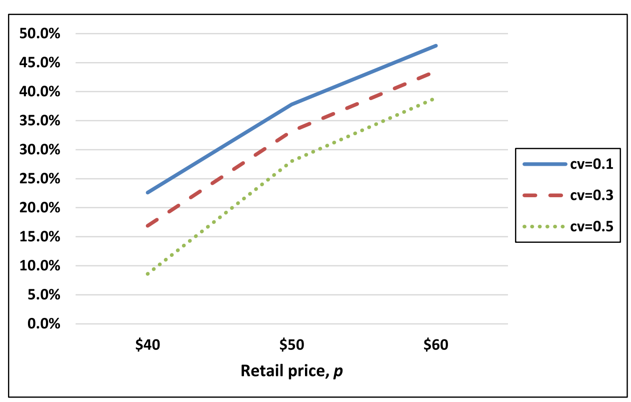

Fig. 8 Commission rate in cv and retail price ($gw(R)$ = \$20, $gw(M)$ = \$50)

Hypothetically, as the wholesale price increases well beyond normal levels as seen in Fig. 9 (regular wholesale price, w = \$30), CS-VMI becomes more attractive to the retailer, even when offered with a low commission rate. This indicates that, under supply-side disruptions, the value of CS-VMI to the consignee is more pronounced due to its price risk hedging benefits. Consistent with this observation, both the percentage improvement in supply chain profit and service level over the base case increase with rising wholesale prices, demonstrating the enhanced utility of CS-VMI in volatile business environment (Fig. 10 and Fig. 11). For instance, in case of a 100% increase in the manufacturing cost (from c=\$20 to \$40) and the wholesale price (from w=\$30 to \$60) respectively, the retailer's threshold value of the commission rate to engage in CS-VMI is as low as 5.4% as seen in Fig 9 (with cv= 0.3 and p=\$75).

Yet, for the same hypothetical stress test scenario depicting the procurement cost increase in the upstream supply chain, the percentage improvement in supply chain profit (16.75%) and the gain in service level (23.7%) show a significant increase as in Figs. 10 and 11.

5.2.5 Summary of sensitivity analysis of performance metrics

The numerical analysis of the CS-VMI contract yields intriguing insights into how different parameters, jointly or in isolation, affect stakeholder outcomes and overall supply chain performance. Table 5 summarizes how each performance metric (supply chain profit, percentage improvement of profit over the base case, service level improvement over the base case, and the commission rate) is affected by individual parameters (cv of demand, retail price, brand loyalty, and customer loyalty) considered in the numerical experiments.

Fig. 10 Stress test: Percentage improvement in profit (c = \$40, p = \$75, cv = 0.3, $gw(M)$ = \$35)

Supply chain profit Local profits at either the consignor or consignee increase when the other party bears a high loss of goodwill penalty.

Percentage improvement in supply chain profit over the base case The highest percentage improvement in supply chain profit over the base case occurs under conditions that result in the lowest baseline profit: high cv of demand, low retail price p, high $gw(M)$, and low $gw(R)$. This reflects the higher potential for improvement when operating under generally challenging conditions.

Service level improvement over the base case As observed in the numerical experiments, the business conditions that promote service level improvement align closely with those that yield the highest percentage improvement in supply chain profit over the base case. Specifically, both metrics improve with high cv of demand, low retail price p, high $gw(M)$, and low $gw(R)$.

AQ3 **Fig. 9** Stress test: Commission rate (p = \$75, c = \$40, cv = 0.3, $gw(M)$ = \$35)

Fig. 11 Stress test: Improvement in the service level (c = \$40, p = \$75, cv = 0.3, $gw(M)$ = \$35)

Table 5 Sensitivity analysis of performance metrics to key parameters

Performance metrics	Parameter setting	
	Maximize	Minimize
Supply chain profit	Low *cv*, high retail price (*p*), low *gw(M)*, low *gw(R)*	High *cv*, low retail price (*p*), high *gw(M)*, high *gw(R)*
Percentage improvement in supply chain profit	High *cv*, low retail price (*p*), high *gw(M)*, low *gw(R)*	Low *cv*, high retail price (*p*), low *gw(M)*, high *gw(R)*
Improvement in service level	High *cv*, low retail price (*p*), high *gw(M)*, low *gw(R)*	Low *cv*, high retail price (*p*), low *gw(M)*, high *gw(R)*
Commission rate	Low *cv*, high retail price (*p*), high *gw(M)*, low *gw(R)*	High *cv*, low retail price (*p*), low *gw(M)*, high *gw(R)*

Commission rate When designing a supply contract in a decentralized setting, the vendor must establish an incentive mechanism that aligns the interests of both the vendor and the retailer. To incentivize the retailer to adopt the proposed contract over the baseline RMI approach, the vendor's coordination offer must be sufficiently appealing, often in the form of a higher commission rate. With CS-VMI, in particular, under conditions favourable to the consignee (e.g., low *cv* of demand, high retail price p, high $gw(M)$, and low $gw(R)$), the consignor should prioritize establishing a contract, often by offering a higher commission rate. On the contrary, under less favourable conditions for the consignee, even a relatively low commission rate offered may be adequate to secure participation by the retailer, given the underlying risk mitigation and coordination benefits of the CS-VMI contract.

It is evident that the diversity of supply chain conditions, characterized by different parameter configurations, calls for tailored contract designs that ensure mutual benefits. Both parties must understand their operating context and objectives to implement a contract structure that properly balances incentives, shares risks, and distributes additional gains generated.

5.2.6 Practical implications and insights

Drawing from the normative model and numerical experiments, this study offers several practical insights for supply chain decision-makers operating within the CS-VMI framework. First, the consignor can introduce a fair, vendor-initiated contract under consignment terms to address demand uncertainty, especially when partnering with a risk-averse retailer. By carefully evaluating the proper risk-reward balance between the consignor and the consignee, managers can proactively design CS-VMI agreements that reinforce the consignor's strategic position while offering the consignee reduced financial exposure, a relevant and important consideration for products with limited shelf life.

Second, an effective CS-VMI contract design should incorporate tailored incentives aligned with product characteristics and the consignee's preference. Findings from sensitive analysis suggest that variations in demand and cost settings significantly influence the suitability of specific incentive structures. For instance, the consignor should adjust commission rates based on the consignee's exposure to demand volatility or customer loyalty. For products with limited shelf life, incentives should be linked to sales behaviour and seasonal patterns, such as incorporating expiration-based buy-back clauses.

Third, the results of numerical experiments highlight that CS-VMI extends beyond transactional coordination between the consignor and the consignee. It serves as a strategic platform to promote long-term partnerships through joint planning and transparent information sharing. A trust-based CS-VMI arrangement, through careful calibration of service levels, inventory ownership, and commission structures, can mitigate operational conflicts and strengthen contract resilience in volatile markets.

6 Conclusion

As one of the first papers to apply the newsvendor approach to study the CS-VMI contract, this research advances the body of literature on CS-VMI by providing a structured analysis of vendor-initiated coordination policies for limited shelf-life products. It addresses a key challenge in supply chain design by examining decisions related to incentive alignment, inventory ownership, and risk mitigation. By focusing on risk-averse retailers and the perishability constraints of products within the CS-VMI framework, the study offers a deeper understanding of the dynamics of supply contracts in volatile environments. It contributes to a more integrated view of supply chains by promoting mechanisms for incentive alignment and shared value creation. As modern supply chains grapple with growing volatility, adaptive and incentive-compatible contracts can offer promising strategies for building more responsive supply networks.

This paper presents insights into the effectiveness of the CS-VMI arrangement for products with a short selling season, focusing on how the consignor can design incentives compelling enough to encourage consignee participation. By transitioning from traditional RMI to CS-VMI, the consignee seeks to mitigate understocking and overstocking risks, enabling a more effective allocation of the additional profits generated. The research shows analytically how the commission rate can be derived to make the contract incentive aligned for supply chain partners. Through simulation experiments, the paper further demonstrates how various supply chain scenarios can yield contracts that not only benefit individual stakeholders at the local level but also improve overall system performance.

Given that the consignee holds no legal ownership of the products and functions merely as the consignor's agent, it can fully benefit from participating in the CS-VMI contract with minimal to no additional risk. Meanwhile, beyond achieving the desired market exposure for limited shelf-life products, the consignor gains greater command under the proposed CS-VMI contract compared to other CS agreements. It is worth noting that the increased control in order placement and inventory ownership granted by the CS-VMI contract allows the consignor to position inventory at the retailer in anticipation of market demand. This is in contrast to the well-known just-in-time (JIT) system, a pull-based approach in which the inventory replenishment decision occurs in response to the actual market demand. It is clear that the value of CS-VMI, as a push-based contract, becomes even more apparent when companies operate in environments marked by heightened uncertainty, volatility, and adversity.

More broadly, this research on the CS-VMI contract holds important implications for creating shared value (CSV). By implementing CS-VMI, businesses can reduce inventory waste, particularly for high-fashion items or perishable goods, without sacrificing service levels. This approach fosters a leaner and more resilient local supply network. Additionally, well-structured incentives (e.g., revenue-sharing, risk-sharing agreements, etc.) can strengthen support for local manufacturers and retailers, helping to mitigate recurring risks for the system and promote sustainable partnerships.

With the frequency of disruptive events growing in the global business arena, a natural extension of this research should lead to the assessment of the effectiveness of CS-VMI under the potential impact of supply-side disruptions (e.g., random shipping delays, volume shortages, logistics infrastructure disruptions, etc.). Applying simulation experiments to business scenarios involving disruptive risks should enrich the scope of discussion and provide possible insights into the remedies (e.g., revenue sharing, option contracts, etc.) to be used alongside CS-VMI. Also, the integration of digital technologies (e.g., real-time data analytics, blockchain technology, etc.) holds potential for enhancing the execution of supply contracts and presents a promising direction for future research. In particular, the adoption of blockchain-driven smart contracts with embedded incentives could be studied for their impact on coordination efficiency within supply chains. It should also be noted that the paper focuses on a structure featuring a single consignor and a single consignee, which can be viewed as a limitation. Future research could extend the model to more reality-based supply chain initiatives involving multiple retailers, increasing its practical relevance and contributing further to the evolving research stream on collaborative supply contracts. AQ4

Funding The authors did not receive support from any organization for the submitted work.

Data availability Not applicable

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.
The authors have no competing interests to declare that are relevant to the content of this article.

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Journal : **Large 12063**	Article No : **549**	Pages : **17**	MS Code : **549**	Dispatch : **10-4-2025**

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