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A BUYBACK CONTRACT MODEL FOR DUAL-SOURCING SUPPLY CHAINS UNDER SUPPLY DISRUPTIONS AND IMPERFECT QUALITY

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Abstract
Unlike most existing research on supply chain coordination that focuses on the relationship between a single supplier and a single retailer/wholesaler, this study investigates a buyback contract mechanism between one buyer and two competitive suppliers within a decentralized supply chain. The proposed model incorporates both upstream supply risks and downstream demand uncertainty to determine the optimal ordering strategies for the retailer and the optimal pricing strategies for both suppliers. Within this framework, the buyback contract is utilized to capture the critical trade-off between inventory policies and disruption risks. Furthermore, the model analyzes the impacts of stochastic demand and disruption risks on contract parameters, providing important managerial insights for buyback contract design. Finally, a numerical example is provided to demonstrate the problem-solving procedure and solutions. Findings indicate that competitive supplier scenarios with buyback guarantees secure higher expected profits than standard contracts, providing a framework for optimizing ordering and pricing strategies.
Keywords: Newsvendor problem; Buyback contract; Supply disruptions; Outsourcing; Supply risk management; Dual sourcing

INTRODUCTION

Outsourcing has attracted considerable attention as a strategic mechanism enabling organizations to achieve their operational objectives. This is especially critical for companies that focus on core competencies to maintain a competitive edge in a rapidly changing global market (Friedman, 2005). However, an increased reliance on the competitive advantages of the supply chain as a whole simultaneously increases exposure to supply risks (Svensson, 2000; Christopher et al., 2002). Due to the upstream position of suppliers in the supply chain, supplier-related issues often result in significant and highly visible consequences. While a substantial body of literature has been reported in the general area of supply chain management, relatively little research has conducted deep investigations into the critical area of supply chain disruptions and their operational impacts.

When a delivery disruption occurs, the purchasing firm usually suffers immediate damage due to lost production capability, completion delays, and potential customer defection (Ruiz-Torres and Mahmoodi, 2007). Supply disruptions triggered by unexpected natural or man-made disasters—such as earthquakes, fires, floods, hurricanes, labor strikes, economic crises, or terrorist attacks—can cause temporary supply interruptions. Although the probability of such catastrophic events is relatively low, their business impact can be severe. A well-known example emphasizing the importance of this issue is the 2000 fire that destroyed an electronic components plant in New Mexico, which served as a supplier for both Nokia and Ericsson. Due to the subsequent supply shortage, Ericsson suffered lost sales worth $390 million, leading to a shift in market dominance toward Nokia. In contrast, Nokia successfully managed the risk by sourcing from alternative suppliers, thereby minimizing the negative impacts of the disruption (Latour, 2001). Similarly, the March 2011 earthquake in Japan prompted companies worldwide to restructure their supply chains to mitigate disruption risks and to search for new alternative suppliers for components previously sourced exclusively from Japan (Hookway and Poon, 2011). These real-life examples demonstrate that buyers can mitigate the risk of supply shortfalls and overcome supply process failures by sourcing from multiple suppliers.

How a company copes with such threats depends heavily on the specific type of disruption and the organization's level of preparedness. It is also highly sensitive to the firm's development and sourcing policies, specifically whether it operates at a global level or limits its operations to local partners. Supply chains may apply divergent approaches to manage disruptions. Firms can secure their supply chains, modify inventory management policies to decrease the effects of disruptions, or develop resiliency to execute recovery plans immediately following a disruption. Managing inventory to buffer supply risks through safety stock can be effective; however, this approach increases internal costs related to storage space, obsolescence, and capital investment (Lee and Billington, 1993). With the widespread adoption of leaner business models, contemporary companies typically carry smaller amounts of safety stock. Alternatively, resilience can be achieved through classic redundancy mechanisms or built-in flexibility. To effectively manage supply disruptions while maintaining profitability and operational efficiency, firms can take operational actions to mitigate risks, such as dual sourcing or backup sourcing. In various industries, utilizing a backup supply source has proven to be an efficient strategy for buyers to mitigate unexpected risks (Kleindorfer and Saad, 2005). Therefore, to minimize potential vulnerabilities to supply disruptions, it is essential for companies to consider adopting backup sourcing strategies.

For a typical customer-driven supply chain, the supply of parts and the scheduling of customer orders for finished products must be coordinated efficiently to achieve a high customer service level at a low cost. This coordination becomes even more vital when facing supply disruptions. To facilitate coordination, supply chains resort to supply contracts. In general, the goal is to design contracts that induce channel coordination through appropriate provisions for information sharing and incentives, thereby optimizing overall supply chain performance. Another important function of contracts is that they facilitate long-term partnerships and make operational terms more explicit (Cachon, 2003). Due to globalization and outsourcing, decentralized supply chains have become prevalent. Numerous contract models have been developed to address channel coordination problems in decentralized supply chains, where each independent member maximizes its own self-interest. In particular, buyback contracts, revenue-sharing contracts, and quantity discount contracts have become effective tools for supply chain profit allocation and the ultimate achievement of channel coordination (refer to Cachon, 2003 for more details).

A typical contract design problem in the supply chain coordination literature considers a single supplier selling to a single retailer facing a classic newsvendor problem. Although supply chain risk management focuses primarily on developing supply chain systems that perform effectively under operational risks and recover quickly from disruptions, there remains a lack of contingency strategic policies to determine optimal parameters when facing different modes of disruptions in a supply chain (Iakovou et al., 2010). Unlike most existing research on coordination that focuses on the relationship between a single supplier and a retailer/wholesaler, this work aims to study a contract-based coordination mechanism between one buyer and two suppliers, explicitly considering demand uncertainty and supply risks. Previous studies have presented the concept of dual sourcing as a mitigation strategy (Marley, 2006) and rerouting as a contingency strategy (Tomlin, 2006). However, the existing literature on dual-sourcing supply chains generally focuses on a network with one perfectly reliable supplier and one unreliable supplier. In contrast, the buyback contract in the proposed model is used to capture the trade-off between inventory policies and disruption risks in a dual-sourcing network under the assumption that both supply sources are susceptible to disruption risks. Given different wholesale prices and disruption probabilities for the suppliers, the primary focus of the proposed buyback model is to determine the optimal order quantity allocated to each supplier to maximize the buyer's expected profit.

This study considers the design of a buyback contract when a retailer faces disruption risks, stochastic demand, and imperfect quality. The motivation for considering a buyback contract is that it is one of the most popular contracts in practice, is well-understood in the contract literature, and completely coordinates the supply chain under the assumption of information symmetry. This study addresses several gaps in the extant literature on disruption risk management. First, while existing research on dual-sourcing systems usually considers a near-shore reliable supplier and an off-shore unreliable supplier, this work assumes that both suppliers are susceptible to disruptions with different probabilities. Second, the proposed model applies to disruptions occurring at different stages, such as the production phase (e.g., machinery breakdown) or the distribution phase (e.g., delivery delays). Finally, the proposed model analyzes the impacts of stochastic demand and disruption risks on the contract parameters and derives key managerial insights for the optimal design of buyback contracts.

LITERATURE REVIEW

Three streams of literature are relevant to this study: supply risk management (SRM), sourcing strategy under supply risks, and supply chain coordination using buyback contracts. Consequently, studies addressing these three topics are reviewed and summarized below.

Supply Risk Management

Because of an increasing dependence on suppliers, companies are more exposed to risk events. Therefore, SRM has become a necessary component of supplier management (Zsidisin & Ellram, 2003; Wu et al., 2006). However, the study of SRM has only received significant attention in recent years. Due to the relative newness of the SRM field, the extant research is highly fragmented and lacks a unifying framework (Ellis et al., 2011). Currently, several different classifications of risk, alongside assorted risk methodologies, can be found in the literature.

Supply risk management aims to develop approaches for the identification, assessment, analysis, and treatment of areas of risk in supply chains (Kern et al., 2012). Risk identification involves the recognition and understanding of possible sources of risk. Most of the extant literature has focused on specific sources of supply risk and their groupings (Zsidisin, 2003; Zsidisin & Ellram, 2003; Giunipero & Eltantawy, 2004). The assessment of risks entails the evaluation of both the likelihood and the impact of the risk (Knemeyer et al., 2009; O'Marah, 2009). Several studies have analyzed the qualitative and quantitative methods used by companies to assess supply risks (Zsidisin et al., 2004; Vilko & Hallikas, 2012; Tazelaar & Snijders, 2013; Atwater et al., 2014) and to manage them (Sinha et al., 2004; Tuncel & Alpan, 2010; Hou et al., 2010). Note that these models do not consider supply risk intrinsically. The subsequent supply risk management activity is the monitoring of regular risk. Indicators can be utilized to identify risk levels that remain within acceptable limits but are rising, thereby signaling possible future problems (Blackhurst et al., 2008).

Risk treatment refers to the use of mitigation strategies to either diminish, eliminate, or counteract risks (Schoenherr et al., 2008). Risk mitigation requires actions that reduce the likelihood of a particular risk occurring, minimize its potential impact, or both. Several mitigation tactics could reduce the likelihood and/or severity of supply disruptions, including early supplier involvement (Zsidisin & Smith, 2005), information sharing (Li et al., 2006), buyer–supplier relationship management (Sinha et al., 2004), contingency planning (Tomlin & Wang, 2005; Tomlin, 2006), and sourcing policy and philosophy (Zsidisin et al., 2000). Extant research further suggests that supplier attributes—such as supplier capabilities, performance, and size—influence supply risk (Ellis et al., 2011). Again, these models do not explicitly incorporate supply risk. Furthermore, mitigation and contingency actions are not cost-free. Therefore, passive acceptance is often considered the cost of dealing with risk, although the benefits of mitigation and contingency strategies generally outweigh the losses caused by supply risks. Companies must identify ways to respond quickly to contain damages (Blackhurst et al., 2008; Braunscheidel & Suresh, 2009).

Supply risk management posits that it is the buyer's responsibility to recognize, monitor, and mitigate these supply risks. Various risk events have been observed and researched, such as the disruption of supply; the breakdown of transportation, production, or warehousing; procurement failures; and forecast inaccuracies (Johnson, 2001; Chopra & Sodhi, 2004; Speckman & Davis, 2004). Reflecting the contemporary reality of increased exposure to supply risks, firms are implementing SRM principles to enhance their risk management capabilities. Most prior studies have focused on the various sources of risk, risk assessment methodologies, the impact of such risks on supply chain performance, and the role of several risk mitigation and response tactics. However, these approaches are often either conceptual or limited to proposing frameworks, and they frequently focus solely on predicting disruptive events (Sodhi et al., 2012). Few studies have explicitly examined the management of risks associated with inbound supply (Zsidisin et al., 2004) or presented a mathematical formulation to determine the optimal number of standby suppliers. To address this gap in the literature, this study employs a quantitative approach to analyze supply risks and obtain the optimal sourcing policy for both research and practical application.

Sourcing Strategy Under Supply Risks

Researchers have attempted to mitigate the negative impacts of supply failures by applying various sourcing strategies, such as local versus global sourcing, single versus dual/multiple sourcing, and optimizing order allocations among multiple suppliers (Swink & Zsidisin, 2006). Many studies compare single sourcing with dual or multiple sourcing (Costantino & Pellegrino, 2010; Glock, 2012; Sawik, 2014a). Single sourcing allows firms to reduce sourcing costs and improve relationships with their suppliers; however, this approach may expose buying firms to a greater risk of supply interruption. In addition, while researchers have addressed different mitigation and contingency strategies to reduce the impacts of supply disruptions, the problem remains critical when a firm's single source is disrupted and can no longer fulfill its role.

Operationally, multiple sourcing provides greater assurance of timely delivery and increased volume flexibility by diversifying the firm's total requirements (Kirytopoulos et al., 2010). Aissaoui et al. (2007) presented a comprehensive review of extant single and multiple sourcing models. Recently, researchers have increasingly studied dual sourcing in the context of supply chain disruptions. Tang (2006) proposed robust strategies for mitigating disruption effects, while Pochard (2003) discussed an empirical solution based on dual sourcing to reduce the likelihood of disruptive events. Tomlin (2006) compares two strategies—holding inventory and dual sourcing—in terms of their effectiveness at mitigating supply risks. A manufacturer can increase system reliability either by holding more inventory or by sourcing from a perfectly reliable, albeit more expensive, supplier. Tomlin's analysis demonstrates that as supply failures become less frequent and more durable, dual sourcing (diversification) becomes preferable to holding inventory. Similarly, Tomlin and Snyder (2007) consider a supply chain comprising one unreliable supplier and one perfectly reliable supplier. In their model, inventory is dynamically adjusted based on the threat level indicated by an advisory system. They show that the presence of a threat advisory system significantly impacts inventory and dual-sourcing decisions. Chopra et al. (2007) also evaluate a supply chain with both an unreliable and a perfectly reliable supplier, where the unreliable supplier is subject to both disruption risk and recurrent risk. They demonstrate that bundling these two types of risks may lead managers to underutilize the reliable supplier. Furthermore, they assert that firms should order more from the reliable, costlier supplier if disruption risk is the primary threat. Notably, in this body of literature, one supplier is generally assumed to be completely reliable.

Carbone (2003) considered cost and risk factors in the supplier selection problem and the associated decision regarding the required number of suppliers. Berger et al. (2004) argued that a supply disruption or the interruption of the inbound supply network could paralyze the functionality of the entire supply chain. They presented a decision-making process using a decision tree approach to identify the optimal number of suppliers needed in the presence of risks. Ruiz-Torres and Mahmoodi (2007) extended Berger et al.'s (2004) model to incorporate the cost of losses incurred when a partial set of suppliers fails to deliver. Their model evaluated scenarios where the probability of supplier failure is equal across all available suppliers, as well as cases where this probability varies. Berger and Zeng (2006) studied optimal supply base size under several scenarios determined by various financial loss functions, operating cost functions, and the probabilities of simultaneous supplier failures. Sarkar and Mohapatra (2010) proposed a decision tree approach to determine the optimal size of the supply base, considering limited supplier failure scenarios. Wu and Olson (2008) utilized chance-constrained programming, data envelopment analysis, multi-objective programming, and simulation for vendor selection in a supply chain facing risk. Tajbakhsh et al. (2007) presented a review of multiple-sourcing inventory models that consider supply risks. More recently, Meena and Sarmah (2013) developed a mixed-integer non-linear programming model for order allocation by a manufacturer/buyer among multiple suppliers under disruption risks. Their model accounts for varying capacities, failure probabilities, and quantity discounts for each supplier, with the objective of minimizing total costs. Sawik (2013) proposed a mixed-integer programming model for selecting resilient suppliers against disruptions and determining optimal order quantities among them.

Supply Chain Coordination Using Buyback Contracts

In a buyback contract (or return policy), the supplier commits to repurchasing unsold inventory from the buyer at the end of the selling season at a specified per-unit buyback price (which is lower than the wholesale price). This mechanism aims to improve channel coordination, induce the buyer to order more from the supplier, and share risks (Mantrala & Raman, 1999). In this arrangement, contrary to a price-only contract, the manufacturer shares the risk of poor demand outcomes. Various types of buyback contracts have been discussed in the literature. Pasternack (1985) was the first to identify that buyback contracts can coordinate the fixed-price newsvendor model while allowing for arbitrary allocation of the total supply chain profit. Both Pasternack (1985) and Lariviere and Porteus (2001) discuss return policies within a single manufacturer–retailer channel utilizing newsvendor-type demand. Taylor (2002) and Krishnan et al. (2004) combine buyback contracts with sales-rebate contracts to coordinate a newsvendor model with effort-dependent demand. Wang (2004) developed a generalized newsvendor model to analyze coordinated quantity decisions between the manufacturer and the buyer. Moreover, Cachon and Lariviere (2005) demonstrate that buyback contracts are mathematically equivalent to revenue-sharing contracts under the assumption of a fixed retail price. Bernstein and Federgruen (2005) show that buybacks coordinate the price-setting newsvendor only if the supplier earns zero profit. Buybacks have been used extensively in sectors such as publishing, fashion apparel, and cosmetics (Kandel, 1996; Emmons & Gilbert, 1998). Wang and Gerchak (2001, 2002) and Cachon (2003) provide excellent recent reviews of this literature.

Wang et al. (2010) explore a model in which a firm can source from multiple suppliers and/or exert effort to improve supplier reliability. For both random capacity and random yield types of supply uncertainty, they propose a process improvement model in which successful improvement efforts increase supplier reliability (meaning the delivered quantity, for any given order, is stochastically larger post-improvement). They conclude that dual sourcing is favored over process improvement if the supplier reliability heterogeneity is high in the case of random capacity. Davarzani et al. (2011) studied a single-product setting in which a firm can utilize single, dual, or multiple sourcing to manage potential disruptions. They conclude that dual sourcing provides the firm with the opportunity to reroute orders (away from a low-quality supplier) following a disruption. However, monopoly problems can arise after a disruption, causing the buying firm to lose bargaining power. Conversely, in triple sourcing, while the initial setup cost might be higher, competition between the remaining two suppliers persists after a disruption, preventing unreasonable price increases. Sawik (2014b) presents a stochastic mixed-integer programming approach for integrated supplier selection and customer order scheduling in the presence of disruption risks under single or dual sourcing strategies. The suppliers are assumed to be located in two different geographical regions: the producer's region (domestic suppliers) and outside the producer's region (foreign suppliers).

Although the literature cited above extensively discusses dual sourcing, there is a distinct paucity of research addressing newsvendor problems where *both* suppliers are considered unreliable.

MODEL DEVELOPMENT

One of the standard building blocks for modeling order quantity decisions under stochastic demand is the newsvendor model. Since the newsvendor model represents the starting point for the analysis of supply chain contracts, an extensive treatment of the standard one-period, one-product newsvendor model is utilized in this study.

The newsvendor model

Consider a one-period setting consisting of a supplier selling to a newsvendor retailer facing stochastic demand. The retail price of an item is fixed at r per unit. The retailer allocates Q units of shelf space to an item. Any unsold inventory is salvaged at s per unit, and a goodwill penalty cost g_b is incurred for every unit of unsatisfied demand. The stochastic demand D has a density function $f(x)$ and a distribution function $F(x)$. Let $S(Q) = \min(Q, D)$ denote the expected sales and $E(D)$ the expected demand. Then, $S(Q)$ can be written as:

$$S(Q) = Q\int_{Q}^{\infty} f(y)dy + \int_{0}^{Q} yf(y)dy = \mathrm{Q} - \int_{0}^{Q} F(y)dy$$

Furthermore, let $I(Q) = (Q - D)^{+} = Q - S(Q)$ be the expected leftover inventory, and $L(Q) = (D - Q)^{+} = E(D) - S(Q)$ be the expected lost sales. If the buyer's marginal cost per unit is c_b(with $c_b < r$) and the unit wholesale price is w, then the retailer's profit function is:

$$\pi(\mathrm{Q}) = rS(Q) - g_b L(Q) - c_b(Q) - [wQ - sI(Q)] \qquad (1)$$

In Eq. (1), the coordination mechanism focuses on the buyer's order quantity. Facing stochastic demand, the buyer must determine an optimal order quantity Q^{*}that maximizes the expected profit prior to the start of the selling season.

The decentralized supply chain

Firms in a decentralized supply chain make decisions independently. Consider two competing suppliers in a decentralized supply chain serving a single retailer who faces random customer demand and disruption risks. Since demand is unknown before the sales period begins, emergency replenishment orders are not permitted. When a disruption occurs at a supply source, it is assumed that no orders will be fulfilled during the selling period. Let p_i denote the probability of a disruption for supplier i. Disruptions are assumed to be triggered by either a catastrophic super-event or a unique event. In this study, we assume that Supplier 2 is affected only by unique events, whereas Supplier 1 is vulnerable to both categories of failure.

Under a buyback contract, the buyer orders Q_i units at the start of the season at a wholesale price of w_i per unit from supplier i, and may return up to Q_i units at the end of the season for a buyback price $\mathrm{b} < \mathrm{w}_i < r$ per unit instead of the salvage value s. A goodwill penalty cost g_b is incurred for every unit of unsatisfied demand. Assuming all firms are risk-neutral (i.e., each firm seeks to maximize its expected profit), the following section models a retailer and two competitive suppliers in a decentralized supply chain, aiming to maximize the expected profit for each respective party.

a. The retailer's decision process

The retailer determines the order quantities that maximize expected profit based on the wholesale and buyback prices established by the suppliers. When there is no disruption in the system (with a probability of $(1 - p_1)(1 - p_2)$), the expected profit for the retailer, $\pi_{r0}(\mathrm{Q}_1, \mathrm{Q}_2)$, can be obtained through classical newsvendor problem analysis:

$$\pi_{r0}(Q_1, Q_2) = rS(Q_1, Q_2) - g_b L(Q_1, Q_2) - [w_1 Q_1 + w_2 Q_2 - bI(Q_1, Q_2)]$$
$$= (r + g_b)(Q_1 + Q_2) - [r + g_b - b]\int_0^{Q_1+Q_2} F(x)dx - g_b E(D) - (w_1 Q_1 + w_2 Q_2)$$

Likewise, when a disruption occurs at Supplier 1 (with a probability of $p_1(1-p_2)$), the order from Supplier 2 can be used to satisfy demand, and the buyer's profit function $\pi_{r1}(Q_2)$ becomes:

$$\pi_{r1}(Q_2) = (r + g_b)(Q_2) - [r + g_b - b]\int_0^{Q_2} F(x)dx - g_b E(D) - w_2 Q_2$$

Moreover, when disruptions occur at both suppliers (with a probability of $p_1 p_2$), the profit function $\pi_{r12}(Q_1, Q_2)$ is provided by

$\pi_{r12}(Q_1, Q_2) = -g_b E(D)$.

Therefore, the retailer's total expected profit for given Q_1 and Q_2 is formulated as:

$$\Pi_r(Q_1, Q_2) = (1-p_1)(1-p_2)\pi_{r0}(Q_1 + Q_2) + p_1(1-p_2)\pi_{r1}(Q_2) + p_1 p_2 \pi_{r12}(Q_1, Q_2) \quad \text{(a.1)}$$

Proposition 1. The retailer's total expected profit is jointly concave in Q_1 and Q_2.

Proof. The first-order partial derivatives of the expected profit with respect to Q_1 and Q_2 are respectively given by:

$$\frac{\partial \pi_r(Q_1, Q_2)}{\partial Q_1} = (1-p_1)(1-p_2)[(r + g_b) - (r + g_b - b)F(Q_1 + Q_2) - w_1]$$

and

$$\frac{\partial \pi_r(Q_1, Q_2)}{\partial Q_2} = (1-p_1)(1-p_2)[(r + g_b) - (r + g_b - b)F(Q_1 + Q_2) - w_2] + p_1(1-p_2)[(r + g_b) - (r + g_b - b)F(Q_2) - w_2$$

It can be deduced that the Hessian matrix of the expected profit is negative definite. Thus, the optimal order quantities from Supplier 1 and Supplier 2 are as follows:

$$Q_1^* = F^{-1}\left(\frac{r+g_b-w_1}{r+g_b-b}\right) - F^{-1}\left(\frac{p_1(1-p_2)(r+g_b)-(1-p_2)w_2+(1-p_1)(1-p_2)-w_1}{p_1(1-p_2)(r+g_b-b)}\right) \quad \text{(a.2)}$$

$$Q_2^* = F^{-1}\left(\frac{p_1(1-p_2)(r+g_b)-(1-p_2)w_2+(1-p_1)(1-p_2)w_1}{p_1(1-p_2)(r+g_b-b)}\right) \quad \text{(a.3)}$$

The decision process of suppliers

Assuming both suppliers are competitive, each supplier maximizes their expected profit by setting the wholesale price w_i before the order is placed by the retailer.

Let $0 < \beta < 1$ be the proportion of unsold inventory returned to the first supplier. The expected profit functions for the suppliers are then determined respectively by:

$$\pi_{s1}(Q_1, Q_2) = (1-p_1)(1-p_2)[w_1(Q_1, Q_2)Q_1 - b\beta I(Q_1, Q_2)] \quad \text{(b.1)}$$

and

$\pi_{s2}(Q_2, Q_1) = p_1(1-p_2)[w_2(Q_2, Q_1)Q_2 - bI(Q_2)] - (1-p_1)(1-p_2)[b(1-\beta)I(Q_1, Q_2)]$ (b.2)

The suppliers can determine their wholesale prices according to the retailer's demand functions in Eq. (a.2) and Eq. (a.3), yielding:

$w_1(Q_1, Q_2) = r + g_b - (r + g_b - b)F(Q_1 + Q_2)$

and

$w_2(Q_1, Q_2) = r + g_b - (1-p_1)(r + g_b - b)F(Q_1 + Q_2) - p_1(r + g_b - b)F(Q_2)$

The optimal solutions can be obtained via numerical methods, as the first-order conditions do not yield closed-form solutions for w_i and b. The preceding analysis demonstrates that the wholesale price is a critical factor in determining the retailer's optimal order quantities. Intuitively, the second supplier's order quantities, as well as their profitability increase, are highly dependent on the first supplier's wholesale price and supply uncertainty.

Proposition 2.

(a) When there is no disruption at either supplier, $w_1 = w_2$, and the buyer will only order from the first supplier.

(b) If a disruption occurs at the first supplier, the second supplier receives more orders, and the optimal order quantity is $Q_2^* = F^{-1}[\frac{p_1(r+g_b)-w_2+(1-p_1)w_1}{p_1(r+g_b-b)}]$.

NUMERICAL EXAMPLE

A numerical example is presented to illustrate the theoretical results. The following parameters are used to solve the problem: r = 16, g_b= 8, p_1={0.1, 0.3}, p_2={0.1, 0.3}, β= {01., 0.4, 0.7, 0.9}, assuming demand follows a uniform distribution over $[300{,}500]$. The computational results are summarized in Table 1. These results demonstrate that Supplier 1 can leverage a lower cost if a reliable supply is provided. Consequently, the retailer achieves a higher expected profit when disruption risks decrease for both suppliers.

CONCLUSIONS AND DISCUSSIONS

The current work provides a joint examination of inventory management and disruption risks through a buyback policy, investigating important managerial insights regarding buyback contract design. This study considers both upstream risks and uncertain demand within a dual-sourcing supply chain to determine appropriate ordering strategies for the retailer and pricing strategies for both suppliers. Optimal solutions are obtained based on the assumption of uniformly distributed demand. The findings enable the retailer to determine order quantities for each supplier under disruption risks, while allowing suppliers in a competitive environment to set wholesale prices that maximize their expected profits.

Based on these findings, several actionable recommendations can be drawn for practitioners managing real-world dual-sourcing operations under supply uncertainties and quality imperfects. First, managers must avoid the "safe supplier" fallacy that assumes near-shore or secondary backup suppliers are entirely reliable. Since both supply sources in practice face non-zero disruption risks (p_1, p_2), ordering strategies should be dynamically adjusted based on joint disruption probabilities rather than relying on static supplier hierarchies. Second, buyback mechanisms should be actively leveraged as a strategic risk-sharing tool. Standard wholesale price contracts leave the buyer bearing the brunt of inventory and disruption exposure; incorporating buyback parameters (β) offers downside protection, enabling retailers to order larger quantities and secure higher expected profits for the entire channel. Third, suppliers facing higher disruption risks can compensate buyers by offering higher buyback rates alongside competitive wholesale prices, whereas highly reliable suppliers can command premium pricing with reduced buyback obligations. Finally, quality inspection and defect management should be explicitly embedded into the buyback framework so that non-conforming items from imperfect quality yields do not consume downstream holding capacity.

Future studies may focus on constraints related to strategic policies, such as minimum percentage allocations of order quantities assigned to different suppliers. Extending this approach to accommodate price-dependent demand or linear demand functions represents another promising direction for future research.

Table 1. Optimal solutions with r = 16, g_b = 8

Case	p_1	p_2	β	w_1^*	w_2^*	Q_1^*	Q_2^*	Π_{s1}^*	Π_{s2}^*	Π_r^*
1	0.1	0.1	0.1	500	0	13.33	16	5533.62	0.00	2489.688
2	0.1	0.1	0.4	500	0	13.33	16	5938.52	0.00	2489.688
3	0.1	0.1	0.7	500	0	13.33	16	6343.41	0.00	2489.688
4	0.1	0.1	0.9	500	0	13.33	16	6613.35	0.00	2489.688
5	0.1	0.3	0.1	500	0	13.33	16	4303.92	0.00	1865.313
6	0.1	0.3	0.4	500	0	13.33	16	4618.85	0.00	1865.313
7	0.1	0.3	0.7	500	0	13.33	16	4933.77	0.00	1865.313
8	0.1	0.3	0.9	500	0	13.33	16	5143.71	0.00	1865.313
9	0.3	0.1	0.1	158.88	341.11	13.49	16	1456.52	2353.75	2318.614
10	0.3	0.1	0.4	158.88	341.11	13.49	16	1775.24	2194.39	2318.614
11	0.3	0.1	0.7	158.88	341.11	13.49	16	2093.97	2035.02	2318.614
12	0.3	0.1	0.9	158.88	341.11	13.49	16	2306.45	1928.78	2318.614
13	0.3	0.3	0.1	158.88	341.11	13.49	16	1132.85	1830.69	1590.033
14	0.3	0.3	0.4	158.88	341.11	13.49	16	1380.74	1706.74	1590.033
15	0.3	0.3	0.7	158.88	341.11	13.49	16	1628.64	1582.80	1590.033
16	0.3	0.3	0.9	158.88	341.11	13.49	16	1793.91	1500.16	1590.033

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