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Information Sharing in the Two-Level Manufacturer-Retailer Supply Chain Using the PSSCA

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ABSTRACT

In this paper, a model of a two-level manufacturer-retailer supply chain (TLMRSC) under uncertainty in information sharing (IS)/not sharing information (NIS) was developed. The manufacturer serves as the leader and determines the wholesale price and quality standards, while the retailer serves as the follower and decides the retail price and service level. In this case, there will be a difference between the profit from IS and NIS. According to the results based on PSSCA, the retailer first establishes the retail price before deciding on the service level in line with that price in the NIS. Depending on the selections provided by the retailer, the manufacturer sets the wholesale price and quality standard. The manufacturer obtains market information from the retailer, and the retailer receives manufacturer information on the quality standard. This makes it clear that the leader and retailer have raised the selling price while reducing the service level.

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1. Introduction

Due to the fast changes in the environment, technological improvements, and the globalization of markets, businesses increasingly need to maximize the performance of the total TLMRSC rather than simply individual enterprises (Cao, 2007). As a result, in the present economic climate, a company's long-term success depends not only on its performance but also on collaboration with other companies that are involved in the SC's upstream (suppliers) and downstream (customers) segments (distributors and retailers). Businesses attempt to collaborate more closely with their SC partners to survive and compete successfully in this climate (Wang et al., 2023). Participants in the SC work closely together and share a certain amount of knowledge, resources, and risks to achieve common goals. SC coordination is the word used to describe this kind of long-term interaction (Cao et al., 2023). Coordination may increase the amount of shared benefits and provide each member a share of the additional benefit, which cannot be created by each member separately (Ghahremani Nahr et al., 2022).

Supply chain coordination and significant reliance depend on high IS ratio exchange because it is one of the primary variables in coordination (Jafari & Safarzadeh, 2023). Due to the rapid changes in the environment, the development of technology, and the integration of the world economy, there is more uncertainty in connection to information in the market today. The SC is negatively impacted by several factors, some of which are, in brief, an increase in manufacturing, inventory, transportation, and labor costs, a decline in service standards, and a breakdown in relationships between SC participants. IS ratio exchange can thereby improve chain performance throughout the SC. Even though each link in the chain has unique information needs and outputs, the size, accuracy, and correctness of this information have an impact on how well the SC functions. Given that each of the organizations involved in the SC can speed up the flow of information by sharing their information with other organizations, improving the performance of the SC and enabling it to respond to changing customer needs more quickly, it is possible to state that IS will give the organization a competitive advantage over time.

To increase SC coordination, chain participants must communicate information. As a result, resource utilization in factories is enhanced, and costs associated with the SC are reduced. Better information management helps factories satisfy customer demand. Information is now more accessible than it was five years ago. Due to decision-makers in SC management having better access to information, there are more chances and prospects for improving SC efficiency (Zhou & Benton, 2007). Given that the top organizations and businesses in the world today emphasize SC coordination as a new source of competitive advantage and that IS is a crucial component of creating coordination in the SC, it is imperative to understand the factors that have a direct or indirect impact on the amount of IS in the SC. If a suitable model for IS in the SC is available, it is feasible to identify practical components and change them to measure and evaluate the benefits of IS. The assumption that information is always appropriately transferred among the participants is made in the literature on IS in the SC (Ghahremani-Nahr et al., 2023).

If neither side cancan verify the accuracy of the other's information, manufacturers and retailers may exchange false information to further their interests. This informational distortion might reduce benefit levels or stop the exchange of SC knowledge (Ghahremani Nahr & Zahedi, 2021). Another critical obstacle to IS is companies' reluctance to share their knowledge for fear that their suppliers would reveal it to their competitors. Information leakage may adversenegatively affect all parties involved in the SC, including the participants themselves (Esmaeili & Kafashian Ahar, 2019). The management of IS is essential and affects an organization's and a SC's performance. Research shows that effective information exchange in the SC significantly reduces delays, maintenance costs, safety reserves, and associated costs. But what makes the flow of information controllable and gives the phrase "management of IS" significance is understanding the indicators impacting it at the level of the SC (Guzman et al., 2022). On the other hand, it is helpful to understand the chain's current condition of information flow when investing in information systems and integrated systems. Additionally, it is useful for gap assessments and before-after comparisons of IT projects and infrastructures (Farajpour & Yousefli, 2018). Thanks to recent developments in business information technology, such as enterprise resource planning systems, information can be easily shared across SC partners. However, depending on the SC's structure, demand patterns, and operational considerations like costs, the benefits of information exchange across SC members may vary (Agrawal et al., 2009). Due to the exchange of demand information, all parties in the SC are aware of the ultimate market demand for the products and utilize this information to forecast future demand. The distributor acts as a go-between for the retailer and the supplier, managing themselves as an intermediary between the retailer's demand and supply (Manfredi & Capik, 2022).

The primary purpose of this paper is to design a model for the TLMRSC problem, in which actors of the supply chain share their helpful information. IS is the most important issue discussed in this paper, and its results have been examined in terms of IS and NIS. Also, a new hybrid algorithm of PSO and SCA called PSSCA is designed to solve the problem.

The paper is organized as described below: The literature review relevant to the SC and IS ratio exchange is evaluated in the second section. TLMRSC in IS/NIS is shown mathematically in the third part. In addition, the PSSCA is introduced in this section. The fourth portion of the study looked at the sensitivity of the numerical example and the issue to the essential model parameters, as well as how it affected the actions of the manufacturer and retailer. The fifth section is when we finally talk about our conclusions after solving the mathematical models.

2. Literature review

The definition of the quality standard and service level in a TLMRSC, as well as IS ratio exchange, are covered in this section of the literature review. Wei and Zhao (2013) examined the concepts underlying three different product collection modalities used by manufacturers, retailers, and third parties when making decisions. Yan et al. (2014) developed an SC finance system including a manufacturer, a retailer, and a business bank. Nakasumi (2017) proposed a blockchain-based approach to address the issues with the SC. Data exchange between manufacturers, suppliers, and customers becomes crucial to enable reaction to market fluctuations. Amiri et al. (2018) considered employing an iterative search strategy to resolve the leader challenge in the TLMRSC model. Ebrahimi et al. (2019) developed an advertising contract model for a TLMRSC. They assumed that demand fluctuates and is affected by the retailer's marketing efforts. Wu et al. (2019) investigated multi-source and vertical IS in a SC with several suppliers and associated supply uncertainty, as well as two competing retailers and a customer. Guan et al. (2020) investigated the issue of demand IS due to marketunclear demand. Harris et al. (2020) presented reverse SCs and emphasized how they differ from forwarding SCs by modeling the IS ratio and the utilization of information technology. Chernonog (2021) developed a general model of a TLMRSC engaging through a revenue-sharing consignment contract. Dai et al. (2022) examined the TLMRSC in four IS scenarios: NIS, forward IS, reverse IS, and total IS. Wang et al. (2022) developed a game theory model with a manufacturer giving services to two competing retailers, and they found the game equilibrium. Guzman et al. (2022) created an inspection game in which one inspector leads a team of inspectors who report and exchange inspections as the scenario unfolds but do not work together in any other way. Tai et al. (2022) calculated the advantages of IS in a TLMRSC. According to IS with and without quantitative disclosure agreements and IS/NIS, they assessed the difference between total TLMRSC profitability under each scenario.

Examining the research gap between the previous research and the current article shows that there is no sharing of market information regarding the determination of quality standards and product standard level along with retail and wholesale prices. Also, the mathematical model in this situation (IS) with NIS has not been comprehensively investigated. Finally, the hybrid algorithm has not been used in any of the papers to solve the problem. Therefore, in this paper, the introduction of PSSCA to solve the problem has been discussed. The following can be listed as research gaps based on the numerous studies:

- Presenting a TLMRSC model in IS/NIS of the various retailers.
- Considering the service level offered by the retailer.
- Consider the quality standard set by the manufacturer.

3. Problem definition and modeling

In this section, a TLMRSC in IS/NIS is discussed. In this SC, the manufacturer gives the product to the retailer, who then sells it to customers. The retailer has information on the market demand. As a result, the retailer sets the retailer price (p) and the service level (s). Additionally, the manufacturer creates the item at a cost (c) and sells it to the retailer at a wholesale price (w) with a quality standard (q). The demand is regarded as non-linear and a normal distribution function in the models described in this section. The manufacturer is free to disclose quality standards to the retailer, and the retailer is free to provide market information to the manufacturer. The following assumptions might be presented to formulate the TLMRSC:

- The manufacturer decides on wholesale price and quality standard; the retailer chooses retail price and service level.
- The manufacturer is viewed as the follower and the retailer as the leader.
- Demand is a non-deterministic function of the retail price, quality standard, and service level.

T $X(P,\varepsilon) = D(p) + \varepsilon$ y. The deterministic component in the demand function, $D(p)$, linear and depends on the parameter p.. The final price of the product is given as the demand function, which is a linear and declining function:

$$D(P) = \alpha - \beta p + \delta s - \gamma q + \varepsilon, \quad \alpha,\beta,\delta,\gamma \geq 0 \tag{1}$$

In the aforementioned relationship, β is the retailer price elasticity coefficient, δ is the service level elasticity coefficient, and γ is the product demand's responsiveness to the quality standard. Additionally, $\varepsilon \sim N(0,\sigma^2)$ is a normal distribution function with the variance σ^2.

3.1. NIS

The manufacturer cannot derive the retailer's projection data in this situation because the retail price and service level are decided at the last level. In other words, if the retailer doesn't give the manufacturer market knowledge, the manufacturer will have to base the wholesale pricing and quality standard on the retailer's decides. As a result, the retailer in this instance determines the retailer price and service level before determining the wholesale price and quality standard.

$$E(\pi_{rn}) = E\left(\left(\alpha - \beta p_n + \delta s - \gamma q + \varepsilon\right)\left(p_n - w_n\right) \mid \Gamma\right) - \lambda \frac{s^2}{2} \tag{2}$$

$$E\left(\pi_{fn}\right) = E\left(\left(w_n - c\right)\left(\alpha - \beta p_n + \delta s - \gamma q + \varepsilon\right) - \delta\lambda \frac{s^2}{2} - \gamma\varphi \frac{q^2}{2}\right) \tag{3}$$

$$E\left(\pi_{scn}\right) = E\left(\pi_{rn}\right) + E\left(\pi_{fn}\right) \tag{4}$$

The profit function for the retailer is shown in equation (2). The total TLMRSC profit is made up of the profits from the retailer and the manufacturer, as shown in equations (3, 4), respectively.

Theorem 1: In the absence of IS, the retailer's profit function is a concave function, and retailer price and service level are as follows:

Proof 1: The concavity of the retailer's profit function needs to be demonstrated in order to assess the service level and the best retailer pricing. The function's Hessian matrix needs to be defined as follows.

$$H = \begin{bmatrix} \dfrac{\partial^2 E[\pi_{rn}]}{\partial {p_n}^2} & \dfrac{\partial E[\pi_n]}{\partial p_n \partial s} \\ \dfrac{\partial E[\pi_{rn}]}{\partial s \partial p_n} & \dfrac{\partial^2 E[\pi_{rn}]}{\partial s^2} \end{bmatrix} = \begin{bmatrix} -2\beta & \delta \\ \delta & -\lambda \end{bmatrix} \tag{5}$$

In order for the optimal amount of service level and retailer price to be calculated according to the following relations, it must be $2\beta\lambda - \delta^2 \geq 0$. Therefore, the relation $\delta \leq \sqrt{2\beta\lambda}$ must always be maintained. Due to the lack of IS, first the retailer determines the price and service level. Based on this, in order to achieve the optimal price and service level, $\frac{\partial E(\pi_{rn})}{p_n} = \frac{\partial E(\pi_{rn})}{s} = 0$ should be done. As a result, we have:

$$\frac{\partial E\left(\pi_{rn}\right)}{\partial p_n} = 0 \rightarrow p_n = \frac{\alpha - q\gamma + s\delta + \varepsilon + \beta w_n}{2\beta} \tag{6}$$

$$\frac{\partial E\left(\pi_{rn}\right)}{\partial s} = 0 \rightarrow s = \frac{\delta\left(p_n - w_n\right)}{\lambda} \tag{7}$$

By combining the above two equations, the retailer price as well as the service level in NIS is obtained as follows.

$$p_n^* = \frac{\alpha\lambda - q\gamma\lambda - \delta^2 w_n + \beta\lambda w_n}{-\delta^2 + 2\beta\lambda};\ s^* = \frac{\delta(-\alpha + q\gamma + \beta w_n)}{\delta^2 - 2\beta\lambda} \tag{8}$$

On the other hand, in order to determine the wholesale price and quality standard, by deriving the above function with respect to w_n and q, you get the following values.

$$w_n = \frac{\begin{pmatrix} \delta^4\varepsilon + \beta(\alpha - q\gamma)\delta^3\lambda - \beta\delta^2(\alpha + c\beta - q\gamma + 4\varepsilon)\lambda \\ +2\beta^2(\alpha + c\beta - q\gamma + 2\varepsilon)\lambda^2 \end{pmatrix}}{\left(\beta^2\lambda\left(-2\delta^2 + \delta^3 + 4\beta\lambda\right)\right)} \tag{9}$$

$$q = \frac{\lambda\left(\alpha\delta^3 + c\beta\left(-\delta^2 + 2\beta\lambda\right) + \beta\left(\delta^2 - \delta^3 - 2\beta\lambda\right)w_n\right)}{\gamma\delta^3\lambda + \left(\delta^2 - 2\beta\lambda\right)^2\varphi} \tag{10}$$

3.2. IS

In this part, the manufacturer receives information from the retailer about the service level and the retailer receives information from the manufacturer about the quality standard. The manufacturer and retailer will make more profit as a result of this and the IS ratio (θ). Equations (11-13) demonstrate the TLMRSC profit.

$$E(\pi_{ry}) = E\left((\alpha - \beta p_y + \delta s - \gamma q + \varepsilon)(p_y - w_y) \mid \Gamma\right) - (1-\ \theta)\lambda\frac{s^2}{2} \tag{11}$$

$$E(\pi_{fy}) = E\begin{pmatrix} (w_y - c)(\alpha - \beta p_y + \delta s - \gamma q + \varepsilon) & \\ -\delta\lambda\frac{s^2}{2} - \gamma\varphi\frac{q^2}{2} - \theta\lambda\frac{s^2}{2} & \mid \Gamma \end{pmatrix} \tag{12}$$

$$E(\pi_{scy}) = E(\pi_{ry}) + E(\pi_{fy}) \tag{13}$$

Theorem 2: The retailer's profit function in the IS has a concave shape, and the ideal retailer price and service level are as follows:

Proof 2: The concavity of the retailer's profit function needs to be demonstrated in order to establish the service level and the best retailer pricing. The function's Hessian matrix needs to be defined as follows.

$$H = \begin{bmatrix} \frac{\partial^2 E[\pi_{rn}]}{\partial p_y{}^2} & \frac{\partial E[\pi_n]}{\partial p_y \partial s} \\ \frac{\partial E[\pi_{rn}]}{\partial s \partial p_y} & \frac{\partial^2 E[\pi_{rn}]}{\partial s^2} \end{bmatrix} = \begin{bmatrix} -2\beta & \delta \\ \delta & -((1-\theta)\lambda) \end{bmatrix} \tag{14}$$

In order to calculate the optimal value of the service level and the retailer price according to the following relations, the value should be $2\beta((1-\theta)\lambda) - \delta^2 \geq 0$. Therefore, the relationship $\delta \leq \sqrt{2\beta((1-\theta)\lambda)}$ must always be maintained. $\frac{\partial E(\pi_{ry})}{p_y} = \frac{\partial E(\pi_{fy})}{s} = 0$ should be done in order to achieve the retailer price and service level in IS. As a result, we have:

$$\frac{\partial E(\pi_{ry})}{\partial p_y} = 0 \rightarrow p_y = \frac{\alpha - q\gamma + s\delta + \varepsilon + \beta w_y}{2\beta} \tag{15}$$

$$\frac{\partial E(\pi_{ry})}{\partial s} = 0 \rightarrow s = -\frac{\delta(p_y - w_y)}{(-1+\theta)\lambda} \tag{16}$$

Also, to determine the wholesale price and quality standard, by deriving the above function concerning w_y and q, you get the following values:

$$w_y = \frac{\left(\begin{array}{c} c\beta(-1+\theta)\left(\delta^2+2\beta(-1+\theta)\lambda\right)+ \\ \alpha\left(\delta^3+\delta^2(-1+2\theta)+2\beta(-1+\theta)^2\lambda\right)- \\ (q\gamma-\varepsilon)\left(\delta^3+\delta^2(-1+2\theta)+2\beta(-1+\theta)^2\lambda\right) \end{array}\right)}{\left(\beta\left(\delta^3+\delta^2(-2+3\theta)+4\beta(-1+\theta)^2\lambda\right)\right)} \quad (17)$$

$$q = \frac{\left(\lambda\left(\begin{array}{c} \delta^2(\alpha+\varepsilon)(\delta+\theta)+c\beta(-1+\theta)\left(\delta^2+2\beta(-1+\theta)\lambda\right)- \\ \beta\left(\delta^3+\delta^2(-1+2\theta)+2\beta(-1+\theta)^2\lambda\right)w_y \end{array}\right)\right)}{\left(\gamma\delta^2(\delta+\theta)\lambda+\left(\delta^2+2\beta(-1+\theta)\lambda\right)^2\varphi\right)} \quad (18)$$

3.3. PSSCA

The main principles of the optimization technique are a collection of criteria that are used to continuously analyze and enhance this random set. There is no assurance that a solution will be discovered in a single run because population-based optimization approaches strive to optimize optimization problems randomly. The likelihood of discovering the global optimum rises with enough random solutions and optimization levels (iterations). Despite the variations in population-based optimization techniques, it is typical to split the optimization process into two levels: exploration and exploitation (Mirjalili et al., 2020). To identify potential areas of the search space, the optimization method first combines random solutions into a set of random solutions with a high degree of randomness. The movement speed in the PSSCA is equally as effective as the equations connected to the search for the solution based on the sin and cos equations. The position update equations shown below are suggested for both levels:

$$\begin{cases} X_i^{t+1} = X_i^t + r_1.sin(r_2).\left|r_3 P_i^t - X_i^t\right| & r_4 < 0.3 \\ X_i^{t+1} = X_i^t + r_1.cos(r_2).\left|r_3 P_i^t - X_i^t\right| & 0.3 \le r_4 < 0.6 \\ \begin{cases} V_i^{t+1} = wV_i^t + c_1 r_1\left(pbest_i - X_i^t\right) + c_2 r_1\left(gbest_i - X_i^t\right) \\ X_i^{t+1} = X_i^t + V_i^{t+1} \end{cases} & r_4 \ge 0.6 \end{cases} \quad (19)$$

where P_i^t is the location of the destination point in the i-th dimension, || denotes an absolute value, and x_i^t is the position of the current solution in the i-th dimension (size) in the t iteration. Additionally, in the new iteration t, x_i^t is the velocity of dimension i. The velocity of dimension i in the current iteration t is known as V_i^t. The current position is represented by X_i^{t+1}. The particle's location in the latest iteration is indicated by X_i^{t+1}. The best position that dimension i has taken so far is denoted by $pbest_i$, and the best position is denoted by $gbest_i$. The cognitive and social parameters are c_1 and c_2, respectively.

The PSSCA has four main parameters: $r_1, r_2, r_3,$ and r_4. The next region's position (or movement's direction) is indicated by the parameter r_1, which may be inside or outside the area between the solution and the destination. The distance that should be traveled toward or away from the destination is determined by the parameter r_2. When calculating the distance, the r_3 parameter allows you to highlight randomness ($r_3 > 1$) or low importance ($r_3 < 1$) for the destination. Finally, the equation's components each have a different value for the parameter r_4. An algorithm must be able to strike a balance between exploration and exploitation in order to identify potential search space regions and eventually reach the global optimum. Equation (19)'s sine and cosine amplitudes are adaptively altered using the following equation in order to balance exploration and exploitation.

$$r_1 = a - t\frac{a}{Max\,it} \quad (20)$$

The maximum number of iterations is $Max\ it$, the current iteration is t, and a is a constant.

3.4. Tuning the PSSCA parameters

Tuning the PSSCA parameters will help it search for solutions more effectively. For each parameter, a set of several levels is established, and an initial value for the parameter is suggested. Then, using equation (21), the answer of model and RPD value is determined.

$$RPD_i = \frac{Fitness_i - Best\,Fitness}{Best\,Fitness} \tag{21}$$

The test result received after each test was administered is referred to in the relationships above as $Fitness_i$. Additionally, the best score across all exams is referred to as $Best\ Fitness$.

Parameter	*Best Level*	*Best Value*
N pop	*3*	*200*
Max it	*3*	*300*
c1	*1*	*1.5*
c2	*2*	*2*
a	*3*	*3*

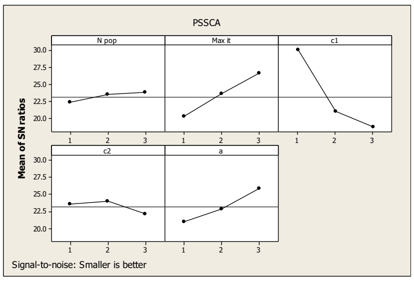

Fig. 1. Mean of S/N ratio for PSSCA

4. Results

The numerical example is examined in this section. The parameters of the TLMRSC are defined in Table (1).

The parameters' values and the arguments presented in the previous section serve as the foundation for decisions regarding retail (retail price and service level) and manufacturer (wholesale price and quality standard) in the IS and NIS scenarios. Table (2) shows the retailer, manufacturer, and total TLMRSC profit in both IS and NIS modes.

Table 1. Values of the initial parameters

θ	φ	γ	δ	λ	β	α	c
0.2	0.3	1.2	1.5	0.6	1.8	20	6

Table 2. Variable decisions in the modes of IS and NIS

Model	π_{sc}^*	π_f^*	π_r^*	s^*	p^*	q^*	w^*
NIS	840.554	348.380	492.174	7.86	18.71	6.29	15.567
IS	875.474	324.728	550.746	2.036	36.789	15.097	31.823

The findings show that, in the absence of IS, the retailer first determines the retailer price before defining the service level in line with it. In this case, the retail price equates to 18.71, the service level to 7.86, and the profit to the retailer to 492.174. Based on the retailer's decisions, the manufacturer determines the wholesale price and the quality standard, which results in a wholesale price of 15.567 and a quality standard of 6.29. Because the manufacturer is a follower, its profit, which equates to 348,380, is smaller than the retailer's profit. In the second situation, when there is an IS ratio of 0.2, the manufacturer learns about the market from the retailer, and the retailer learns about the manufacturer's degree of quality standard. This makes it clear that the market leader and retailer has raised the selling price while reducing the service level. This is being done to reduce costs. The manufacturer increased the wholesale price in reaction to the increase in the retail price and the IS ratio, and he is now required to raise the bar for the quality standard. Because of the higher retail price and lower service level, the retailer's profit increased, while the manufacturer's profit decreased because of the greater quality standard. The total TLMRSC profit has risen by 4.15% in the presence of IS compared to the lack of it. This is demonstrated in Table (3), which examines the effect of the amount of IS using a numerical example.

Table 3. The effect of the θ on TLMRSC profit

θ	w^*	q^*	p^*	s^*	${\pi_r}^*$	${\pi_f}^*$	${\pi_{sc}}^*$
0.1	28.617	15.281	28.933	0.051	543.761	320.367	864.128
0.2	31.823	15.097	36.789	2.036	550.746	324.728	875.474
0.3	34.944	14.672	40.924	4.189	557.108	336.146	893.254
0.4	37.67	13.834	43.107	6.094	579.86	344.254	924.114
0.5	39.723	12.333	43.903	7.343	604.61	348.674	953.284
0.6	40.94	9.913	43.639	7.508	596.175	359.497	955.672
0.7	41.314	7.602	42.695	6.36	545.877	371.371	917.248
0.8	40.969	7.138	41.465	4.2	511.943	382.332	894.275
0.9	40.095	6.741	40.186	1.862	469.499	397.983	867.482

According to Table (3), which demonstrates how much IS ratio is shared between the retailer and the manufacturer, wholesale and retail prices have increased as a result of increased service level and quality standard. Additionally, as IS has increased, manufacturing and quality standard have improved along with service levels. Therefore, based on the IS ratio, the manufacturer and the retailer are trying to increase their profit. The retailer price and service level at various IS, as well as the quality standard and wholesale prices, are compared in Figure 2.

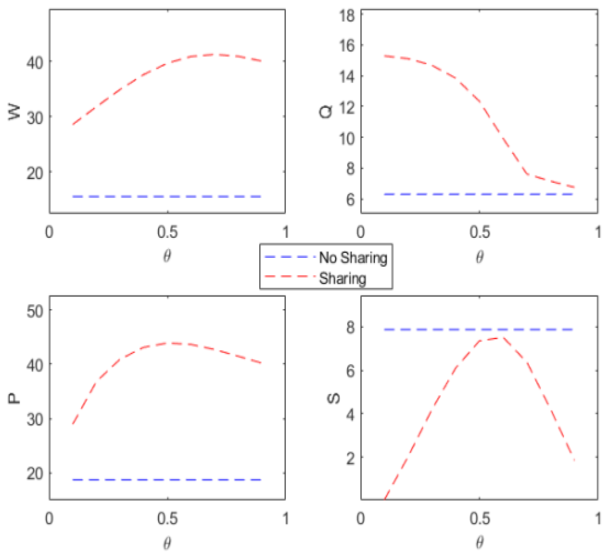

Fig. 2. The effect of the level of IS on decisions

Figure (2) and Table (3) indicate that the existence of a game among TLMRSC actors results in IS leading to a variety of decisions. As a result of more IS, among other things, the manufacturer raises his wholesale price and lowers the quality of his products. As a result, as the IS ratio increases in contrast to those that do not, the manufacturer's profit increases. On the other hand, the retail price and service level originally grew and subsequently reduced as the IS ratio increased. As a result of this action, the retailer's profit rose and later fell. The highest retail profit level reaches 604.61 when the IS ratio is 0.5. A retail profit of 397.983 is the highest when the IS ratio is 0.9. When the IS ratio is 0.6, the total TLMRSC profit will peak at 955.672 units.

As part of the analysis of the continuation of the numerical example, the effects of each issue parameter on the critical decisions made by the manufacturer and retailer, as well as the profits obtained by each SC participant, have been investigated. Then, in each section, the sensitivity analysis for each parameterparameter is shown.

- **The effect of the α**

Table (4) shows the effect of potential demand amount on the decision variables, retailer, manufacturer, and the total TLMRSC profit.

Table 4. The effect of talpha on TLMRSC profit

α	w^*	q^*	p^*	s^*	$\pi_r{}^*$	$\pi_f{}^*$	$\pi_{sc}{}^*$
10	5.168	0.547	5.894	0.683	307.71	246.274	553.984
15	10.367	2.871	11.803	3.589	418.351	304.942	723.293
20	15.567	6.290	18.712	7.860	492.174	348.380	840.554
25	20.766	9.709	25.621	12.136	536.759	394.374	931.133
30	25.965	13.128	32.529	16.410	599.642	456.378	1056.02
35	31.165	16.547	39.438	20.683	637.672	512.345	1150.017

The results in Table (4) demonstrate that when potential demand increases, the influence on these two choice factors has raised the retail price and service level. The retail cost has increased in step with the service level, and the wholesale price has increased in step with the quality standard. In this case, the potential increase in demand leads to higher profit for both the manufacturer and the retailer.

- **The effect of the β**

Table (5) shows the effect of modifying the product price elasticity coefficient on the manufacturer, retailer, and total TLMRSC profit.

Table 5. The effect of the β on TLMRSC profit

β	w^*	q^*	p^*	s^*	$\pi_r{}^*$	$\pi_f{}^*$	$\pi_{sc}{}^*$
1.2	92.875	48.761	117.238	60.952	634.223	514.37	1148.593
1.5	26.724	12.753	33.101	15.942	564.641	441.298	1005.939
1.8	15.567	6.290	18.712	7.863	492.174	348.38	840.554
2	12.308	4.290	14.456	5.369	391.165	264.187	655.352
2.2	10.286	3.005	11.789	3.756	284.988	164.217	449.205
2.5	8.401	1.746	9.275	2.183	125.997	34.667	160.664

The findings of Table (5) demonstrate that as a result of the product's enhanced price elasticity on the market, which has an impact on and lowers demand, both the wholesale price and the retail price have decreased. As a result of the price reduction, the manufacturer and retailer had to downgrade the quality standard and service level. As a result, the retailer and manufacturer profit has decreased. A total examination of the impact of the market's coefficient of product price elasticity on that profit shows that the total TLMRSC profit has dropped due to the increase in this parameter.

- **The effect of the δ**

The effect of modifying the service elasticity coefficient on the profits of the retailer, manufacturer, and total TLMRSC is shown in Table (6).

Table 6. The effect of the δ on TLMRSC profit

δ	w^*	q^*	p^*	s^*	$\pi_r{}^*$	$\pi_f{}^*$	$\pi_{sc}{}^*$
1.3	14.032	6.505	17.285	7.047	416.593	224.524	641.117
1.4	14.830	6.478	18.069	7.558	456.425	284.078	740.503
1.5	15.567	6.290	18.712	7.863	492.174	348.38	840.554
1.6	16.178	5.948	19.152	7.931	522.589	394.631	917.22
1.7	16.620	5.484	19.363	7.765	543.657	358.866	902.523
1.8	16.881	4.946	19.354	7.419	555.462	262.174	817.636

The results of Table (6) demonstrate that as the service level provided by the retailer has grown, so has its elasticity, which has resulted in an increase in the retail price. These decisions have increased wholesale prices and caused a drop in quality standard. According to the results, the manufacturer's profit decreased after the increase while the retail profit climbed with the increase in the service elasticity coefficient.

- **The effect of the γ**

The influence on the decision variables, the profit of the retailer, manufacture, and total TLMRSC is indicated in Table (7) by modifying the product demand response value to the expected quality standard.

Table 7. The effect of the γ on TLMRSC profit

γ	w^*	q^*	p^*	s^*	$\pi_r{}^*$	$\pi_f{}^*$	$\pi_{sc}{}^*$
1	14.416	5.533	17.183	6.917	433.53	102.055	535.585
1.1	14.954	5.888	17.898	7.360	461.276	228.364	689.64
1.2	15.567	6.290	18.712	7.863	492.174	348.38	840.554
1.3	16.269	6.752	19.645	8.440	528.986	456.103	985.089
1.4	17.082	7.287	20.726	9.108	570.886	545.02	1115.906
1.5	18.035	7.913	21.992	9.892	619.994	614.51	1234.504

The findings of Table (8) demonstrate that the manufacturer's product's quality standard has grown as a consequence of rising product demand in response to expected quality standard, and as a result, the wholesale price has also climbed. Along with these increases in values, the retail price and service level have also risen. An improvement in the product demand's responsiveness to the needed quality standard has helped the retailer, the manufacture, and total TLMRSC profit.

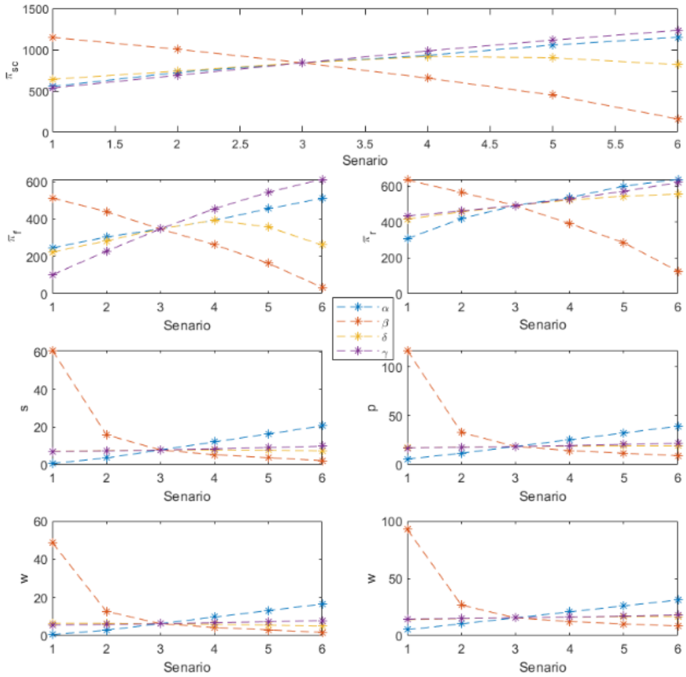

Fig. 3. Decision variables and SC profit in different scenarios

5. Conclusion

Based on the results, it was highlighted that the retailer initially determines the retailer price before deciding on the service level in the absence of IS ratio exchange. In other words, the retail price is equivalent to 18.71, but the service level is equivalent to 7.86. The retailer's profit in this case is equal to 492.174. Based on the retailer's decisions, the manufacturer determines the wholesale price and the quality standard, which results in a wholesale price of 15.567 and a quality standard of 6.29. Because the manufacturer is a follower, its profit, which equates to 348.380, is smaller than the retailer's profit. In the second situation, when there is an IS ratio of 0.2, the manufacturer learns about the market from the retailer, and the retailer knows about the manufacturer's degree of quality standard. This makes it clear that the retailer has raised the retailer price while reducing the service level. This is being done to reduce costs. The manufacturer increased the wholesale price in reaction to the increase in the retail price and the IS ratio, and he is now required to raise the quality standard. The retailer's profit increased because of the higher retail price and lower service level, while the manufacturer's profit decreased because of the more excellent quality standard. The total TLMRSC profit has increased by 4.15% in the presence of IS compared to the NIS. The results also showed that when the retailer and manufacturer's IS ration exchange grew, so did the wholesale and retail price since more market knowledge was gathered and the caliber of the products rose. Additionally, as IS ratio exchange has grown, production and quality standards have improved along with service level. During the sensitivity analysis of the major problem parameters, it was found that the impact of the potential demand on the retail price and service level has increased these two choice variables. Along with improvements in service level and retail prices, the wholesale price has increased in line with the quality standard. In this case, the increased potential demand boosts both the manufacturer's and the retailer's earnings. Additionally, due to the product's improved price elasticity on the market and its effects on demand, both the wholesale and retail prices have decreased. As a result, the profit for the retailer and manufacture has reduced. A different research revealed that the retailer's IS ratio and the service's flexibility grew. As a result, the manufacturer's profit decreased due to the rise, but the retail price and retail profit increased. The sharp reduction in quality standard can explain this. The total profit initially crept up as the service level rose, then it started to fall. Raising the quantity in response to demand for the product has enhanced the quality standard of the product given by the manufacture, and as a result, the wholesale price has also climbed.

The results of this research are in line with the research results of Dai et al. (2022), Guzman et al. (2022), Wang et al. (2022), Tai et al. (2022) and Kurt & Akyol (2023); and states that IS, increase the total income of the actors in the supply chain. In this paper, unlike the primary articles, the uncertainty in the amount of demand is also taken into account, and the researches show that the increase in uncertainty reduces the total profit. Also, the quality standard and service level were discussed, unlike previous research, and the results showed the influence of these factors on retailer and wholesale prices. The results of this research help managers determine the level of IS to increase their profit in the market. Based on this level of IS, optimal retail price, wholesale price, quality standard, and service level are determined.

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