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Measuring the Impact of E-Collaboration on Supply Chain Parties: A Value-Based Management Approach

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ABSTRACT Information sharing in E-Collaboration is increasingly prevalent. This study measures the shareholder value created by E-Collaboration along a supply chain. Three system dynamics (SD) models are developed to investigate the impact of three different information sharing strategies, namely, non-information sharing, partial information sharing, and full information sharing. The impact on different supply chain parties is quantified from the value-based management perspective and economic value added (EVA) is adopted as the value-based performance metric. A numerical example of an E-Commerce retailer-distributor-manufacturer supply chain is presented and followed by profound implications. The analysis demonstrates how value is amplified by E-Collaboration and the unified metric reveals added value's highly imbalanced distribution among different parties. The EVA boost reaped by the manufacturer is about 1000 times more than the retailer's gain under full information sharing. The study provides an original contribution to this stream of research by proposing a uniformed supply chain performance metric, revealing counter-intuitive implications and guiding strategic E-collaboration.

INDEX TERMS Performance metric, economic value added, value-based management, E-Commerce supply chain, E-Collaboration, information sharing.


I. INTRODUCTION

Internet was deemed as the most cost-effective means of driving supply chain integration, and Johnson and Whang defined E-Business as the marriage of the Internet and supply chain integration [1]. Lee and Whang categorized E-Business applications into E-Commerce, E-Procurement and E-Collaboration [2]. In the last decade, E-Commerce and E-Procurement captured most of the attention, in both business press headlines and academic journals. Now it is the era for E-Collaboration to realize its potential impact.

E-Collaboration is defined as over the internet business-to-business interactions that streamline the decisions and activities beyond transactions among supply chain parties, from suppliers to customers [1], [2]. These interactions include information sharing and integration, decision sharing, process sharing, and resource sharing [2]. Information sharing and integration have been mostly studied, with the widespread interest in bullwhip [3]–[5]. Many scholars investigated the

benefits of information sharing [6]–[9], yet not many studies dig deeper to quantify the impact of information sharing on different supply chain participants. Moreover, other themes in E-Collaboration are less explored.

This study aims to measure the value of information sharing through E-Collaboration among different supply chain parties from an innovative angle, the Value-based Management (VBM) approach. Among different supply chain performance evaluation methods, VBM provides a unified performance metric to quantify the impact of E-Collaboration on different supply chain participants [9]. This leads to a better understanding of the motivations and hindrances for different parties to collaborate. Three system dynamics (SD) models are developed to simulate not only the information sharing but also collaborative forecasting and planning among suppliers, distributors and an E-Commerce platform in three different collaboration scenarios. The results of a numerical example lead to insightful managerial implications. The quantification methods presented in this work could also be applied to explore other E-Collaboration themes, i.e. process sharing [10].

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In the following sections, Section 2 reviews past studies in VBM, information sharing and SD and presents the literature gaps to be addressed. Section 3 is the main part of this study which introduces the three EVA SD models. Then a numerical example is presented in Section 4 followed by a detailed analysis of three collaboration scenarios and managerial implications. The last section concludes the study, summarizes the contributions and discusses future directions.

II. RELATED WORK

A. VALUE-BASED MANAGEMENT AND SUPPLY CHAIN PERFORMANCE MEASUREMENT

VBM is devised by Fruhan and Rappaport to maximize shareholder value [11], [12]. VBM can be viewed as a management accounting system which integrates value creation with objectives on the strategical level, performance measurements and cause-and-effect-chains compensation [13]. The VBM approach aims to measure and manage the business to create lasting value for shareholders by developing an integrated framework [14]. Therefore, maximizing value-based performance is the explicit objective of VBM. Economic value added (EVA), among a variety of value-based performance indicators, is far superior in terms of measuring business performance and expressing a value judgement on the company and is therefore adopted as the performance metric in this study [15]. EVA has lower-level performance indicators, which are incapable of guiding daily operational decisions. Therefore, a value driver tree is required to break the decomposed indicators into bottom level decision variables.

Different terminologies and methodologies have been applied to investigate value-based supply chain management (SCM) [16]. Christopher and Ryals identified revenue growth, operating cost reductions, fixed capital efficiency, and working capital efficiency as the four value drivers which link the supply chain strategy and VBM [17]. Waters proposed an EVA-based framework with strategic and operational value drivers which classifies product and market portfolio, supply chain assets, and financial structuring as strategic value drivers; and identified customer retention, sales growth, and supply chain integration as operational value drivers [18]. Value driver trees are used as explanatory frameworks to demonstrate the importance of value drivers in SCM. For the application of VBM in SCM, Dyson stated the significance of operations research in performance management systems design, then a simulation-based multiple metrics performance management approach was proposed by Kleijnen and Smits [19], [20]. Hahn and Kuhn developed an integrated approach to optimizing mid-term level physical and financial supply chain planning with an objective to maximize the EVA [21]. Hahn and Kuhn further improved their VBM model by incorporating risk management into the planning [22]. Zhang and Lam as well as Zhang, Lam and Iris applied VBM tools to analyze cold chain mode choice and proved the superiority of VBM over the traditional optimization approach while dealing with multi objectives [23], [24].

In summary, VBM is an effective tool to measure and maximize shareholder value which has not been widely applied in SCM studies. A distinct advantage of VBM is that it provides an integrated performance metric which covers different aspects of a supply chain, from operation to finance. This advantage enables researchers to quantify and compare the impact of different supply chain strategies on different participants. Yet, no study has been conducted to analyze the impact of information sharing or E-collaboration from the VBM perspective. This work aims to bridge this gap.

B. INFORMATION SHARING AND SUPPLY CHAIN MANAGEMENT

As the key construct of the three flows in SCM, information plays an important role in integrating the flows among different parties and improving the overall supply chain performance [25], [26]. The debate on whether to promote information sharing has last for decades [27]–[29]. Some scholars believe that shared information would generate direct economic value, facilitate decision making and enhance supply chain integration and collaboration [25], [30]–[32]. However, the other stream of academics remains skeptical and concerns about the costs and risks of the sharing practice [33]–[37]. Li, Yan, Wang, and Xia conducted a comparative analysis of 12 representative information sharing models and concluded that information sharing is valuable but the value and affecting factors depend on the analytical methods adopted [38].

Among the first group of scholars, information sharing is believed to be a value generator as it enhances supply chain collaboration [25]. Information asymmetry is deemed to be the main source of the bull whip effect, which describes the distortion and amplification of customer demand upstream in a supply chain [3]. Information sharing could mitigate the bull whip effect by reducing the information asymmetry and forming a strategic supply chain partnership [39], [40]. Strader Lin, and Shaw initially employed simulation analysis to study the impact of information sharing on supply chain performance [41]. The results indicate that supply and demand information sharing could effectively improve the order fulfill rate and reduce the inventory cost as well as the order cycle time. Gavirneni *et al.* [42] firstly proposed three information sharing scenarios, namely, non-information sharing (NIS), partial information sharing (PIS) and full information sharing (FIS). Infinitesimal perturbation analysis is employed by Gavirneni *et al.* [42] to investigate the effect of information sharing upon a two-echelon supply chain under these three scenarios. To quantify the value created by information sharing, Lee *et al.* proposed a two-echelon supply chain model and proved that the supplier's costs and inventories could be reduced by sharing the demand information [30]. Yu *et al.* further investigated the benefit of information sharing in a two-echelon supply chain by proposing a cross-efficiency data envelopment analysis approach [29]. Cheng and Wu focused on how inventory and expected cost could be reduced by promoting information sharing in a dyadic supply chain

with multiple retailers [43]. Dominguez *et al.* investigated PIS by heterogeneous retailers and found that supply chain performance depends on retailers' operational factors like market share and order size [44].

Different studies employ different supply chain performance indicators to examine the benefits of information sharing. Inventory level, lead time and order fulfillment rate are the commonly adopted metrics. Yet limited literature analyzes the value of information sharing in a multi-echelon supply chain [5], [45]. Measuring the overall supply chain performance could better compare different information sharing scenarios and would allow different supply chain parties to evaluate different information sharing strategies from their own perspective. Our study addresses the literature gap by proposing a SD model to evaluate the impact of information sharing in a three-echelon supply chain from the VBM perspective, which assesses the supply chain performance from a holistic view.

C. SYSTEM DYNAMICS

System dynamics, while firstly proposed by Forrester as Industrial Dynamics about six decades ago, has been considerably developed since then and became a legitimate tool of management science [28], [46]. SD is suitable for analyzing and solving complex problems in living systems and it has been widely applied in various domains, including, but not limited to, corporate planning and policy design, economic behavior public management and policy, energy and the environment, dynamic decision making, complex non-linear dynamics, software engineering, and SCM [47], [48]. After the first SD model in SCM was proposed by Forrester 1958, the application of SD in SCM has become more prominent since the last two decades [49]. The re-emergence of SD's application in SCM may attribute to the shifting focus in SCM research to integrated SCM. SD has been employed to investigate the value created by information integration systems (e.g. VMI, e-SCMs) in SCM [27], [50]–[52]. However, to the best of our knowledge, we do not find SD models analyzing information sharing in a multi-echelon e-commerce supply chain in the literature, not to mention from the VBM perspective. Extending from the author's PhD thesis [53], this study is the first using SD models in analyzing information sharing in a multi-echelon E-Commerce supply chain from the VBM perspective.

III. INFORMATION SHARING SYSTEM DYNAMICS MODELS

This section illustrates the general model of a three-echelon supply chain for an E-Commerce platform. The main steps for building this information sharing SD model is briefed as follows based on the modeling steps introduced by Sterman [54].

- Step 1 Problem Articulation: three models are built to investigate the value created by different information sharing strategies.
- Step 2 Formulation of Dynamics Hypothesis: shared information adds value for all the supply chain players.

- Step 3 Formulation of Simulation Model: the models are illustrated later in this section.
- Step 4 Testing: scenarios analysis is presented later in this section.
- Step 5 Policy Design and Evaluation: implications and recommendations are discussed at the end of this section.

The causal loop diagrams (CLD) of each party, namely, the E-Commerce retailer, distributors and manufacturers are presented with the corresponding SD equations. The notation used for this model is shown in Table 1. The parameters and variables used in this model are adopted from well-known SCM SD studies, such as Sterman, Disney and Towill and Gonul Kochan, Nowicki, Sauser, and Randall [50], [51], [54].

A. THE CASUAL LOOP DIAGRAMS AND SYSTEM DYNAMICS EQUATIONS

Following the categories proposed by Gavirneni *et al.*, three models are built to present three information sharing scenarios – NIS, PIS, and FIS. Since the main supply chain operations are similar to these three scenarios, the detailed CLDs and SD equations of the NIS model will be illustrated and only the difference in PIS and FIS will be elaborated [42].

The CLDs of the E-Commerce platform, distributors and manufacturers are presented in Fig 1 to Fig 3a and the structure is based on Sterman and Gonul Kochan *et al.*'s work [51], [54]. The variable at the tail end of an arrow represents an independent variable while the variable at the other side of the arrow is a dependent variable. The arrow represents the cause-and-effect relationship between the variables and the polarity sign on the arrow indicates how the dependent variable changes according to the change of the independent variable. The variables and the casual links form the balancing (negative) and reinforcing (positive) feedback loops. The important loops are highlighted by loop identifiers which are the small curved arrows around a letter "B" (indicating a balancing loop) or "R" (indicating a reinforcing loop). A positive loop reinforces the change along the link while a negative loop undermines the change. The variables in the boxes are stock variables which accumulate over time.

The model presents the full supply chain engagement of a manufacturer, a distributor and an E-commerce platform with planning, production, storage and delivery activities. Both the E-commerce platform and distributor possess their own inventory and will place order from their upstream supplier based on their expected demand. The manufacturer needs to maintain both product inventory and WIP inventory. The production planning is based on the predicted demand and is subject to its own productivity and the supplier's shipment rate.

In Fig 1 to Fig 4, the Customer Order Rate O_p^t depends on the Customer Demand d_p as shown in (1). When the Customer Order Rate is higher than the Order Fulfilment Rate F_p^t (as calculated in (2)), the unfulfilled order accumulates to form the Order Backlog B_p^t as shown in (3). Equations (4) and (5)

TABLE 1. Notation for the information sharing SD models.

Sets and Parameters	
T	Set of time periods, $T \in \{1, 2, \dots, H\}$, where H is the end of the planning horizon
P	Set of supply chain parties, $P \in \{u, e, d, m, s\}$, where u, e, d, m, s presents customers, the E-Commerce platform, distributors, manufacturers, and suppliers respectively
C	Set of two-echelon chains within the supply chain, $C \in \{(u, e), (e, d), (d, m), (m, s)\}$
d^t	Customer demand for the E-Commerce platform at time $t \in T$
$\tilde{\lambda}_p$	Targeted delivery delay with party $p \in P$
β_p	Minimum processing time of party $p \in P$
χ_p	Safety stock of party $p \in P$
L	Manufacturing lead time
α_p	Demand forecasting smoothing interval for party $p \in P$
η_p	Inventory adjustment time with party $p \in P$
τ_m	Work-in-process (WIP) adjustment time at manufacturer m
π_p	Profit per unit product for party $p \in P$
ϕ_p	Inventory cost per unit product for party $p \in P$
φ_p	Backlog cost per unit product for party $p \in P$
Variables	
$I_p^t \in \mathbb{Z}^+$	Inventory level of party $p \in P$ at time $t \in T$
$\tilde{I}_p^t \in \mathbb{Z}^+$	Desired inventory of party $p \in P$ at time $t \in T$
$IC_p^t \in \mathbb{Z}^+$	Inventory coverage time at party at time
$IG_p^t \in \mathbb{Z}^+$	Inventory gap at party at time
$B_p^t \in \mathbb{Z}^+$	Order backlog at party $p \in P$ at time
$\bar{D}_p^t \in \mathbb{Z}^+$	Customer demand forecasted by party $p \in P$ at time $t \in T$

present how B_p^t influences the Desired Shipment Rate \tilde{S}_c^t and the Actual Delivery Delay Λ_p . The Shipment Rate S_c^t is determined by \tilde{S}_c^t and the Fulfilment Ratio FR_p^t as shown in (6). FR_p^t is a function of the Maximum Shipment Rate $max S_p^t$ divided by \tilde{S}_c^t . (7) simplifies the function based on the curve

TABLE 1. (Continued.) Notation for the information sharing SD models.

$\hat{D}_p^t \in \mathbb{Z}^+$	Customer demand forecasting difference at party $p \in P$ at time $t \in T$
$O_p^t \in \mathbb{R}^+$	Order for party $p \in P$ at time $t \in T$
$\tilde{O}_p^t \in \mathbb{R}^+$	Desired order for party $p \in P$ at time $t \in T$
Auxiliary Variables	
$S_c^t \in \mathbb{R}^+$	Shipment rate on chain $c \in C$ at time $t \in T$
$\tilde{S}_c^t \in \mathbb{R}^+$	Desired shipment rate on chain $c \in C$ at time $t \in T$
$max S_p^t \in \mathbb{R}^+$	Maximum shipment rate of party $p \in P$ at time $t \in T$
$F_p^t \in \mathbb{R}^+$	Order fulfilment rate with party $p \in P$ at time $t \in T$
$FR_c^t \in \mathbb{R}^+$	Order fulfilment rate with party $p \in P$ at time $t \in T$
$\Lambda_p \in \mathbb{Z}^+$	Actual delivery delay with party $p \in P$
$R_m^t \in \mathbb{R}^+$	Production release rate of manufacturer m at time $t \in T$
$\tilde{R}_m^t \in \mathbb{R}^+$	Desired production rate of manufacturer m at time $t \in T$
$K_m^t \in \mathbb{R}^+$	Production complete rate of manufacturer m at time $t \in T$
$W_m^t \in \mathbb{R}^+$	WIP inventory of manufacturer m at time $t \in T$
\sim	
$\tilde{W}_m^t \in \mathbb{R}^+$	Desired WIP inventory of manufacturer m at time $t \in T$
$WG_m^t \in \mathbb{R}^+$	WIP inventory gap of manufacturer m at time $t \in T$

proposed by Sterman and (8) shows how $max S_p^t$ is affected by the Inventory Level I_p^t and the Minimum Processing Time β_p [54]. As presented in (9), $I_p^t I_p^t$ varies for different supply chain parties. I_p^t is calculated based on S_c^t (or the Production Complete Rate K_m^t for manufacturers) and the Desired Inventory Level \tilde{I}_p^t , which depends on β_p , the Safety Stock χ_p and the Forecasted Customer Demand \bar{D}_p^t . Equation (10) shows the detailed calculation of \tilde{I}_p^t . The first order exponential smoothing technique is used for the demand forecasting as briefed in (11) and (12) [50], [51], [54]. Equations (13) and (14) depict how I_p^t determines the Inventory Coverage Time IC_p^t and the Inventory Gap IG_p^t . The desired order \tilde{O}_p^t , as shown in (15), is sent to the upstream party in order to minimize IG_p^t .

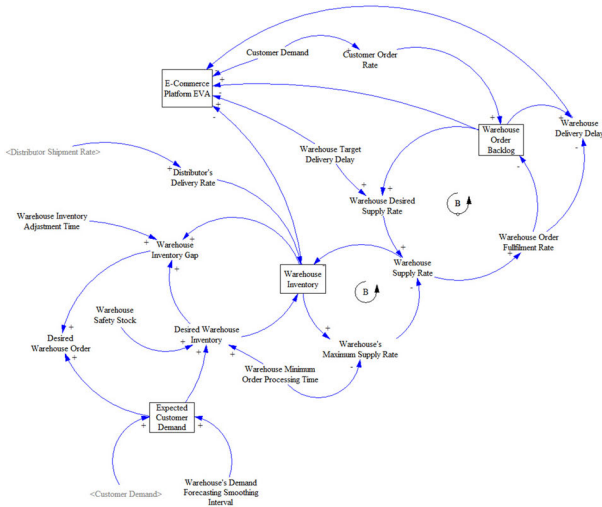


FIGURE 1. The CLD of the E-Commerce platform.

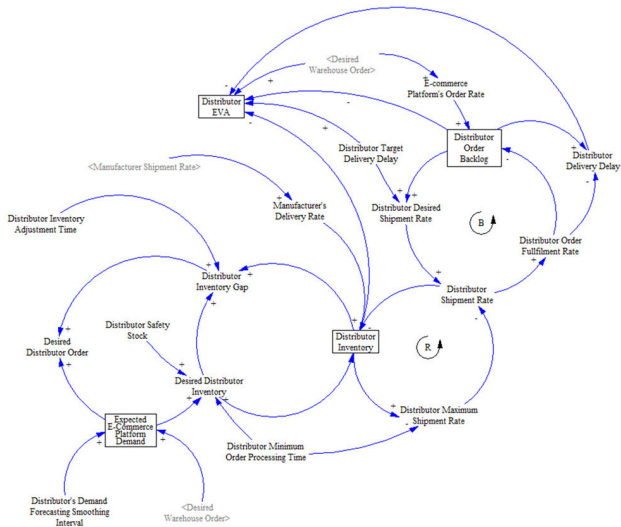


FIGURE 2. The CLD of distributors.

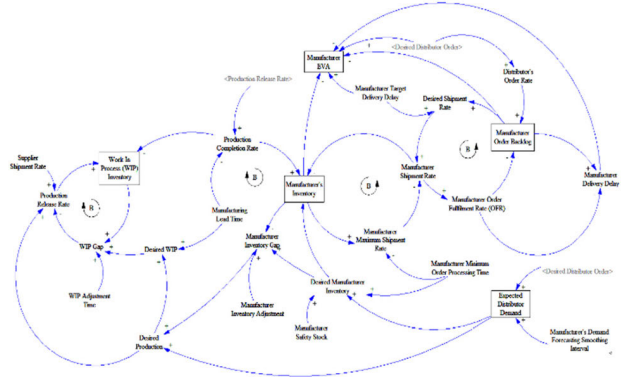


FIGURE 3. The CLD of manufacturers.

The stock management process shown on the right side of the manufacturer's CLD is similar to that of the downstream parties as introduced in the last paragraph, the production process is illustrated on the left side of the CLD. The Desired Production Rate \tilde{R}_m^t aims to match I_m^t to \tilde{I}_m^t base on \tilde{D}_m^t as

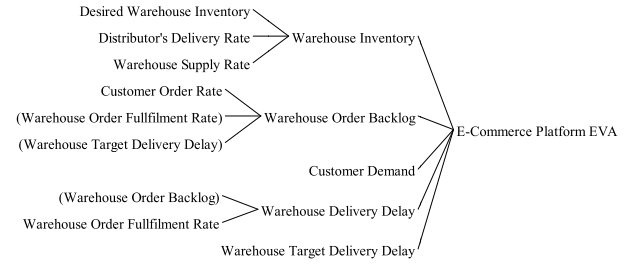


FIGURE 4. E-Commerce platform value driver tree.

shown in (16) and the Production Release Rate R_m^t depends on \tilde{R}_m^t as shown in (17). (18) shows how the WIP Gap WG_m^t is calculated based on the Desired WIP Inventory \tilde{W}_m^t , the WIP Inventory W_m^t and the WIP adjustment time τ_m . \tilde{W}_m^t is to address \tilde{R}_m^t given Manufacturing Lead Time L as shown in (19). \tilde{W}_m^t presents the accumulation of the gap between R_m^t and the Production Complete Rate K_m^t as demonstrated in (20). Finally, K_m^t is calculated based on L using the third order delay technique. As shown in Fig 4, the EVA for each supply chain party is simplified and calculated following (21).

$$O_p^t = \begin{cases} d^t, & \forall t \in T \\ \tilde{O}_p^t, & \forall p \in P \setminus \{e\}, \forall t \in T \end{cases} \quad (1)$$

$$B_p^t = \begin{cases} O_p^t \cdot \tilde{\lambda}_p, & t = 0 \\ O_p^t \cdot \tilde{\lambda}_p + O_p^t - F_p^t, & t \in T \setminus \{0\} \end{cases} \quad (2)$$

$$F_p^t = S_{(n,p)}^t, \quad \forall n, p \in P, \forall (n, p) \in C, \forall t \in T \quad (3)$$

$$\tilde{S}_{(n,p)}^t = B_p^t / \tilde{\lambda}_p, \quad \forall n, p \in P, \forall (n, p) \in C, \forall t \in T \quad (4)$$

$$\Lambda_p^t = B_p^t / \tilde{\lambda}_p, \quad \forall p \in P, \forall t \in T \quad (5)$$

$$S_{(n,p)}^t = \tilde{S}_{(n,p)}^t \cdot FR_p^t, \quad \forall n, p \in P, \forall (n, p) \in C, \forall t \in T \quad (6)$$

$$FR_p^t = \begin{cases} \max S_p^t / \tilde{S}_{(n,p)}^t, \max S_p^t / \tilde{S}_{(n,p)}^t \in (0, 0.5] \\ 0.9 * \max S_p^t / \tilde{S}_{(n,p)}^t, \\ \max S_p^t / \tilde{S}_{(n,p)}^t \in (0.5, 0.7] \\ 0.7 * \max S_p^t / \tilde{S}_{(n,p)}^t, \\ \max S_p^t / \tilde{S}_{(n,p)}^t \in (0.7, 1] \\ 0.98, \max S_p^t / \tilde{S}_{(n,p)}^t \in (1, \infty] \end{cases} \quad \forall n, p \in P, \forall (n, p) \in C, \forall t \in T \quad (7)$$

$$\max S_{(n,p)}^t = I_p^t / \beta_p, \quad \forall n, p \in P, \forall (n, p) \in C, \forall t \in T \quad (8)$$

$$I_p^t = \begin{cases} \tilde{I}_p^t, & t = 0, \forall p \in P \\ \tilde{I}_p^t + S_{(p,l)}^t - S_{(n,p)}^t, & \forall t \in T, \forall p \in P \setminus \{m\}, \\ & \forall l, n \in P, \forall (n, p), (p, l) \in C \\ \tilde{I}_m^t + K_m^t - S_{(d,m)}^t, & \forall t \in T \end{cases} \quad (9)$$

$$\tilde{I}_p^t = (\beta_p + \chi_p) \cdot \tilde{D}_p^t, \quad \forall p \in P, \forall t \in T \quad (10)$$

$$\tilde{D}_p^t = O_p^t + \hat{D}_p^t, \quad \forall p \in P, \forall t \in T \quad (11)$$

$$\hat{D}_p^t = (O_p^t - \tilde{D}_p^t) / \alpha_p, \quad \forall p \in P, \forall t \in T \quad (12)$$

$$IC_p^t = I_p^t / S_{(n,p)}^t, \quad \forall n, p \in P, \forall (n, p) \in C, \forall t \in T \quad (13)$$

$$IG_p^t = (\tilde{I}_p^t - I_p^t)/\eta_p, \quad \forall p \in P, \forall t \in T \quad (14)$$

$$\tilde{O}_p^t = \max(o, \bar{D}_p^t + IG_p^t), \quad \forall p \in P, \forall t \in T \quad (15)$$

$$\tilde{R}_m^t = \max(o, \bar{D}_m^t + IG_m^t), \quad \forall t \in T \quad (16)$$

$$R_m^t = \max(o, \tilde{R}_m^t + WG_m^t), \quad \forall t \in T \quad (17)$$

$$WG_m^t = (\tilde{W}_m^t - W_m^t)/\tau_m, \quad \forall t \in T \quad (18)$$

$$\tilde{W}_m^t = L \cdot \tilde{R}_m^t, \quad \forall t \in T \quad (19)$$

$$W_m^t = \begin{cases} \tilde{W}_m^t, & t = 0 \\ \tilde{W}_m^t + R_m^t - K_m^t, & \forall t \in T \end{cases} \quad (20)$$

$$EVA_p = \sum_{t=1}^{t=T} \pi_p^t \cdot \left(1 - \frac{\Lambda_p^t - \tilde{\lambda}_p^t}{\Lambda_p^t}\right) - \sum_{t=1}^{t=T} \phi_p^t \cdot I_p^t - \sum_{t=1}^{t=T} \varphi_p^t \cdot B_p^t \quad (21)$$

B. THREE INFORMATION SHARING SCENARIOS

Fig 5 to Fig 7 present the CLDs of the three different information sharing scenarios. The red dashed line indicates the information shared among different supply chain parties. In the NIS or the traditional scenario, the downstream supply chain parties only inform the upstream supply chain parties of their Desired Order \tilde{O}_p^t and the upstream parties take \tilde{O}_p^t as their Customer Order Rate O_p^t as shown in (1) and forecast the future demand \bar{D}_p^t based on \tilde{O}_p^t indirectly as shown in (1), (11) and (12). In the PIS scenario, the E-Commerce platform share with the upstream parties their Customer Forecasted Demand \bar{D}_e^t but still make orders based on their Desired Order \tilde{O}_p^t . In this case, the distributors and the manufacturers still stick with \tilde{O}_p^t as shown in (1), but use \bar{D}_e^t for their inventory, procurement, and manufacturing planning as shown in (22) - (24). The final scenario is illustrated in Fig 7, in which the E-Commerce platform fully shares their Forecasted Demand \bar{D}_e^t with the distributors and the manufacturers. The upstream parties take \bar{D}_e^t as O_p^t as shown in (25) and follow (22) - (24) to plan their inventory, procurement, and manufacturing.

$$\tilde{I}_p^t = (\beta_p + \chi_p) \cdot \bar{D}_e^t, \quad \forall p \in P \setminus \{e\}, \forall t \in T \quad (22)$$

$$\tilde{O}_p^t = \max(o, \bar{D}_e^t + IG_p^t), \quad \forall p \in P \setminus \{e\}, \forall t \in T \quad (23)$$

$$\tilde{R}_m^t = \max(o, \bar{D}_e^t + IG_m^t), \quad \forall t \in T \quad (24)$$

$$O_p^t = \begin{cases} d_e^t, & \forall t \in T \\ \bar{D}_e^t, & \forall p \in P \setminus \{e\}, \forall t \in T \end{cases} \quad (25)$$

IV. RESULTS AND DISCUSSION

A. NUMERICAL EXAMPLE AND ANALYSIS

In this section, a numerical example is developed to show the impact of different information sharing strategies, with reference to Gonul Kochan *et al.*'s case study [51]. As shown in Table 2, the stochastic Customer Demand d^t is assumed to follow the gamma distribution with a shape parameter of 5 and an inverse scale parameter of 1.5 [55]. Three SD models simulate the E-Commerce supply chain operations for one year (365 days). The Targeted Delivery Delay $\tilde{\lambda}_p$, Minimum Processing Time β_p , and the Safety Stock χ_p for each supply chain partner are set to be 2 days. The determinate 5-day lead

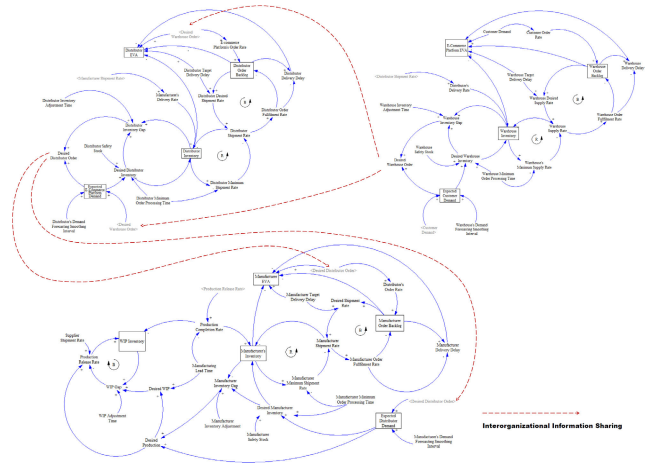


FIGURE 5. NIS CLD of the three-echelon supply chain.

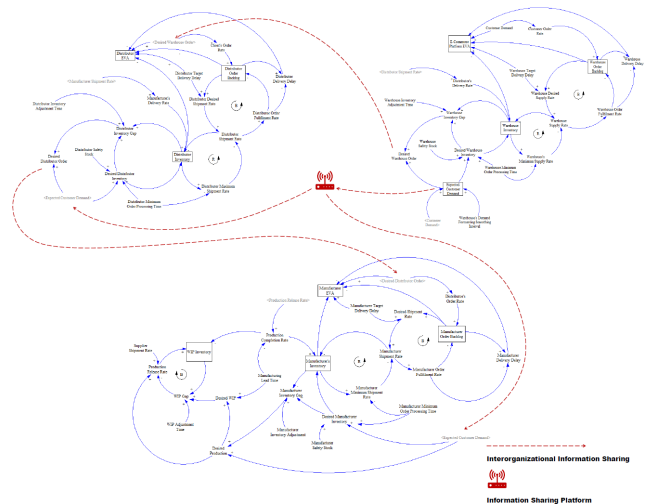


FIGURE 6. PIS CLD of the three-echelon supply chain.

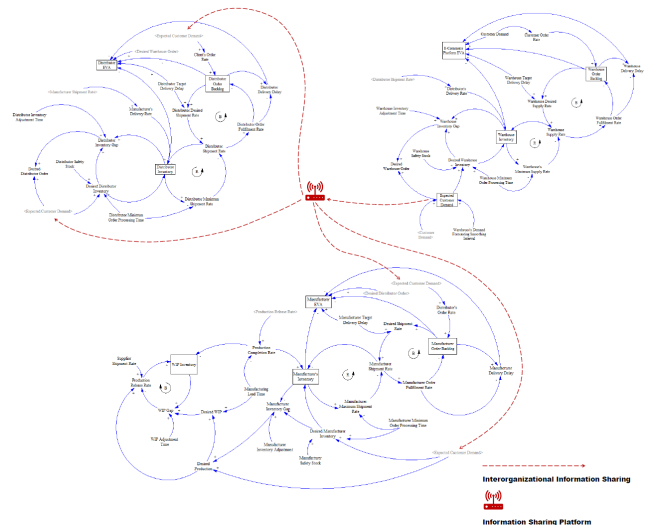


FIGURE 7. FIS CLD of the three-echelon supply chain.

time is adopted in this example and the forecasting smoothing time is also 5 days. The Inventory Adjustment Time η_p and the WIP Adjust Time τ_m are both a day. The Profit π_p of the simulated SKU is assumed to be 100, 80 and 60 currency

TABLE 2. Parameters for SD model numerical example.

Parameter	Value	Unit
T	365	day
d^t	$G \sim (5, 1.5)$	piece/day
$\tilde{\lambda}_p, \forall p \in P$	2	day
$\beta_p, \forall p \in P$	2	day
$\chi_p, \forall p \in P$	2	day
L	5	day
$\alpha_p, \forall p \in P$	5	day
$\eta_p, \forall p \in P$	1	day
τ_m	1	day
π_e	100	cu/piece
π_d	80	cu/piece
π_m	60	cu/piece
ϕ_e	5	cu/piece/day
ϕ_d	5	cu/piece/day
ϕ_m	2	cu/piece/day
φ_e	10	cu/piece/day
φ_d	5	cu/piece/day
φ_m	2	cu/piece/day

unit (cu) for the E-Commerce retailer, the distributor and the manufacturer, respectively. The Inventory Cost ϕ_p is 5 cu per piece per day for the two downstream parties and 3 cu less per piece per day for the manufacturer. For the distributor and the manufacturer, the cost of the backlog order is the same as the ϕ_p , however, the Backlog Cost φ_p is 10 cu/piece/day for the E-Commerce platform since it affects the level of service to the end customers.

Table 3 presents the change in EVA for the three supply chain parties with different information sharing scenarios. As shown in the table, the manufacturer benefits the most from shared information. When no demand information is shared, the manufacturer experiences negative EVA at the end of one-year operations. With partially shared information, though the EVA remains negative, it increases by 95% and is close to making even. While the forecasted customer demand is fully shared, the EVA of the manufacturer reaches 258,361, which is 9,408% more than the EVA of the PIS scenario. The distributor also gains significantly more with shared information. Partially shared information almost increases the EVA of the distributor by half while fully shared information boosts the distributor’s EVA by 782%. Comparatively, the deal is less attractive to the E-Commerce operator since neither information sharing strategy manages to raise its EVA by even 10%. Such differences can be explained by the bull whip effect.

The bull whip effect can be observed in Fig 8. The expected demand becomes higher upstream in the supply chain and so does the desired order. Fig 9 shows how information sharing mitigates the bull whip effect and aligns the desired order of different supply chain parties. To dive deeper, the inventory level of the three supply chain parties with different information sharing scenarios are presented in Fig 10 to Fig 12. It can be spotted that although shared demand information brings down the inventory level for all the supply chain partners, the

TABLE 3. EVA comparison for three information sharing scenarios.

	NIS (cu)	PIS (cu)	FIS (cu)	↑ NIS- PIS	↑ PIS- FIS
E-Commerce Platform EVA	123,462	125,752	137,329	2%	9%
Distributor EVA	35,861	53,224	469,687	48%	782%
Manufacturer EVA	-54,297	-2,776	258,361	95%*	9,408%*

* ABS method is used to get the percentage.

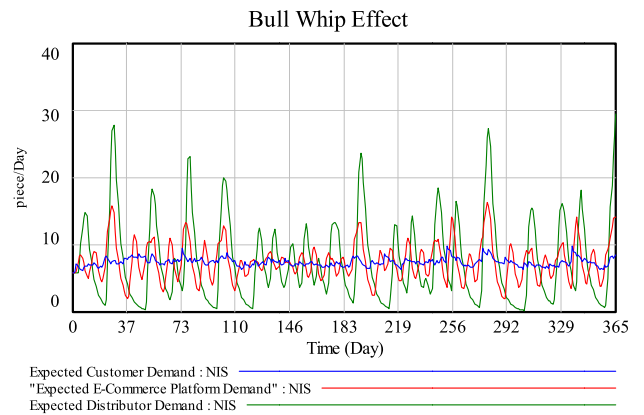


FIGURE 8. The bull whip effect.

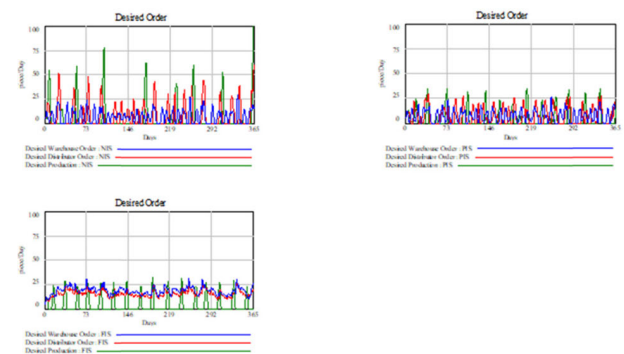


FIGURE 9. Mitigation of the bull whip effect.

manufacturer has the highest inventory level while no information is shared and therefore gains the most by reducing the inventory level. A more interesting phenomenon can be found in Fig 13 to Fig 15. Shared information lowers the backlog order of both the distributor and the manufacturer; however, it does not work on that of the E-Commerce operator. On the contrary, fully shared information slightly increases the backlog order of the E-Commerce platform. This is caused by the reduced shipment rate of the upstream partners as shown in Fig 16.

Another interesting finding from the numerical example is that while overall all supply chain parties benefit when partial information is shared as compared with no information

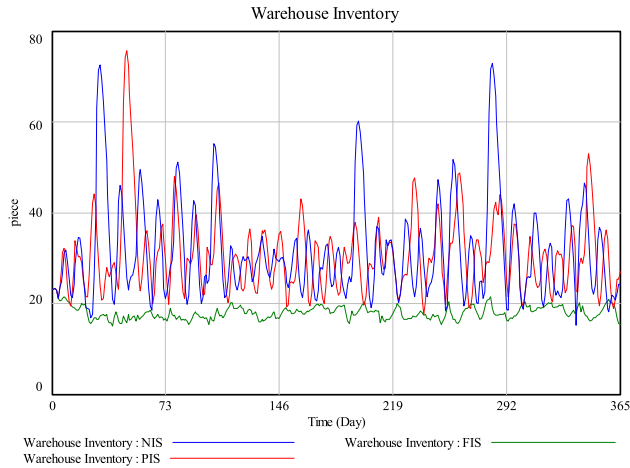


FIGURE 10. E-Commerce operator's warehouse inventory level with three information sharing scenarios.

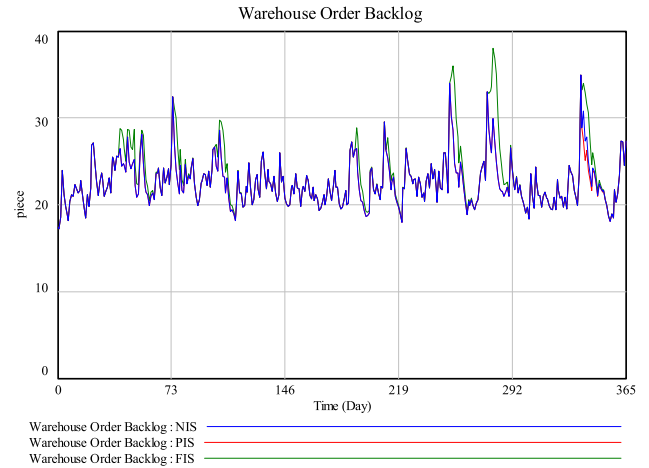


FIGURE 13. E-Commerce operator's warehouse order backlog with three information sharing scenarios.

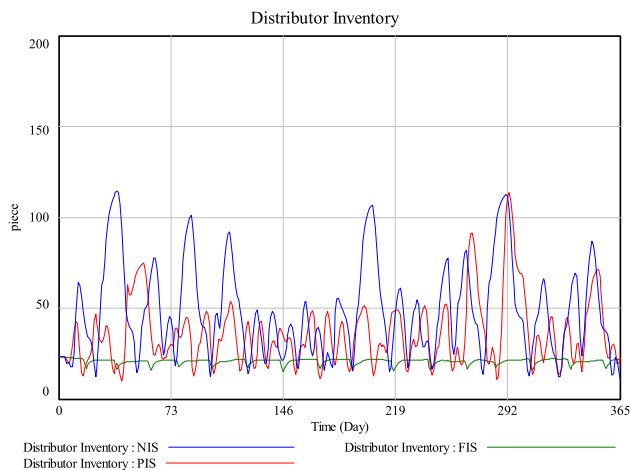


FIGURE 11. Distributor inventory level with three information sharing scenarios.

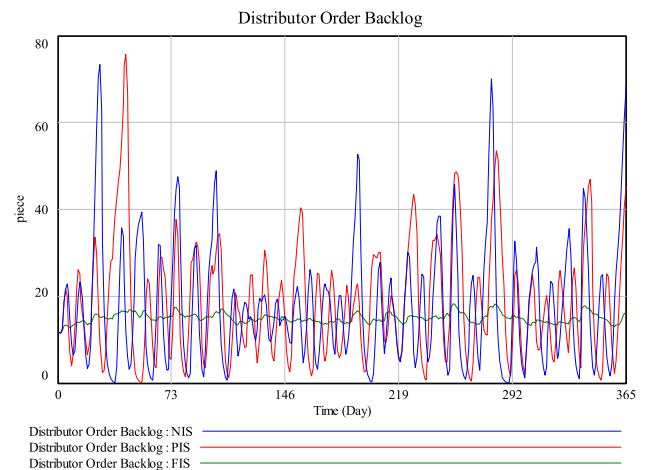


FIGURE 14. Distributor order backlog with three information sharing scenarios.

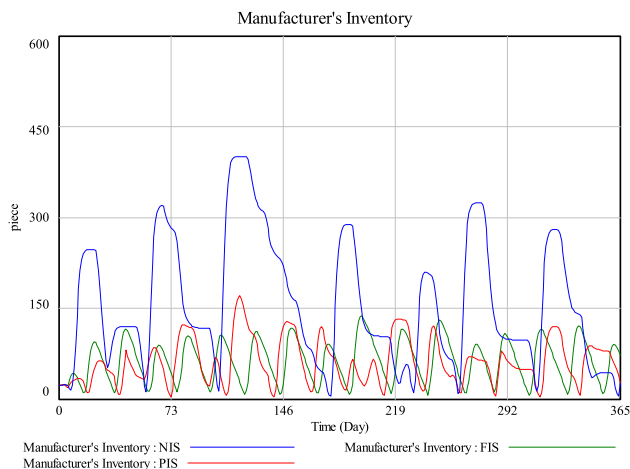


FIGURE 12. Manufacturer inventory level with three information sharing scenarios.

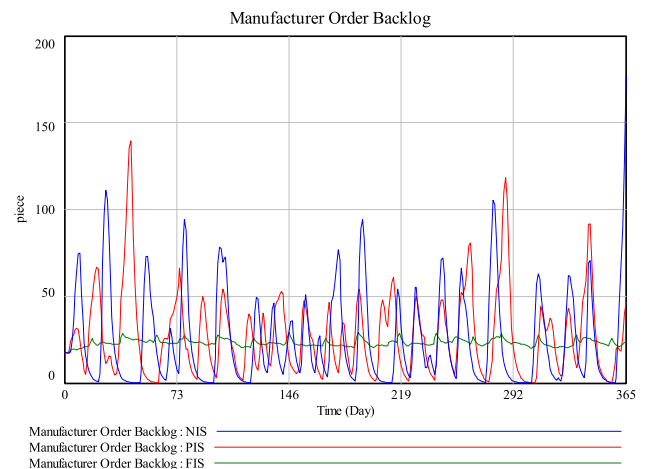


FIGURE 15. Manufacturer order backlog with three information sharing scenarios.

sharing, the benefit is even higher when there is full information sharing. Results show that the EVA is significantly higher in the scenario of full information sharing. The results may be counter-intuitive and lead to an important implication that supply chain parties in an existing E-Collaboration may

reap much greater benefits when they share more information in an effective way. That is, benefits may not be incremental when the degree of information sharing continues to increase. The quantifiable benefits of each supply chain party at various degrees of information sharing can be analyzed through the

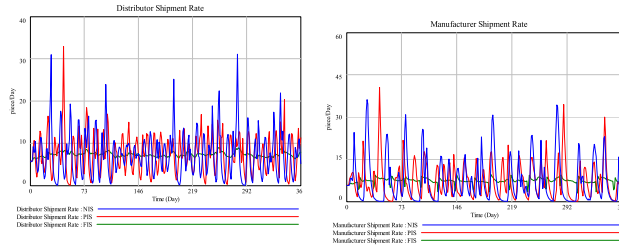


FIGURE 16. Distributor and manufacturer’s shipment rate with three information sharing scenarios.

TABLE 4. Parameters for SD model in different demand scenarios.

Parameter	Value	Unit
T	365	day
d_{high}^t	$G \sim (8, 1.5)$	piece/day
d_{low}^t	$G \sim (2, 1.5)$	piece/day
$\tilde{\lambda}_p, \forall p \in P$	2	day
$\beta_p, \forall p \in P$	2	day
$\chi_p, \forall p \in P$	2	day
L	5	day
$\alpha_p, \forall p \in P$	5	day
$\eta_p, \forall p \in P$	1	day
τ_m	1	day
π_e	100	cu/piece
π_d	80	cu/piece
π_m	60	cu/piece
ϕ_e	5	cu/piece/day
ϕ_d	5	cu/piece/day
ϕ_m	2	cu/piece/day
φ_e	10	cu/piece/day
φ_d	5	cu/piece/day
φ_m	2	cu/piece/day

value-based management approach, which is a major contribution of this study.

Furthermore, the study has shown the usefulness of breaking down the analysis to investigate impacts of varying degrees of information sharing on product order, inventory level, and backlog order of different supply chain parties. As the numerical example shows, the results of these metrics can be very different. This implies that incentives and obstacles of E-Collaboration can be found and analyzed more precisely, then appropriate actions can be taken accordingly. For instance, supply chain parties should discuss and adjust the types of information to be shared with reference to the impact analysis in order to achieve a win-win situation.

B. SENSITIVITY ANALYSIS AND IMPLICATIONS

To better understand the impact of information sharing for different products, a sensitivity analysis is conducted to cover products with different demand, profit margin, and inventory cost. The product studied in the numerical example is deemed as medium in these three aspects.

1) DEMAND

Table 4 presents two other demand patterns used to assess how the product demand would affect the benefits of

TABLE 5. EVA comparison in different demand scenarios.

High Demand	NIS (cu)	PIS (cu)	FIS (cu)	↑ NIS-PIS	↑ PIS-FIS
E-Commerce Platform EVA	174,062	174,348	189,832	0%	9%
Distributor EVA	112,971	126,941	407,479	12%	221%
Manufacturer EVA	-21,109	70,605	240,047	434%*	240%
Medium Demand	NIS (cu)	PIS (cu)	FIS (cu)	↑ NIS-PIS	↑ PIS-FIS
E-Commerce Platform EVA	123462	125752	137329	2%	9%
Distributor EVA	35861	53224	469687	48%	782%
Manufacturer EVA	-54297	-2776	258361	95%*	9,408%*
Low Demand	NIS (cu)	PIS (cu)	FIS (cu)	↑ NIS-PIS	↑ PIS-FIS
E-Commerce Platform EVA	66324.2	65270.7	62350.7	-2%	-4%
Distributor EVA	-7863.07	-31947.9	261965	306%*	920%*
Manufacturer EVA	-223996	-44301.5	155640	80%*	451%*

*ABS method is used to get the percentage.

information sharing for each supply chain party. The results are summarized in Table 5.

As the results suggest, when the demand is high, the manufacturer’s gain from information sharing increases most significantly while switching from NIS to PIS. An interesting finding is that neither the absolute EVA nor the gain from information sharing of the manufacturer is as prominent in the high demand setting comparing with the medium demand case, even the mitigation of the bull whip effect remains the same as shown in Figure 17. This is caused by the high backlog in manufacturer as shown in Figure 18. The same case applies to the distributors. In the high demand scenario, the bottleneck may shift to the processing rate so that the potential of information sharing cannot be fully realized. In the low demand setting, the distributor benefits the most from information sharing in both PIS and FIS scenarios. On the contrary, the downstream player would suffer a small loss by sharing the demand information due to the increased backlog cost. It is a good example to show how the benefits of information sharing could be imbalanced among different supply chain parties.

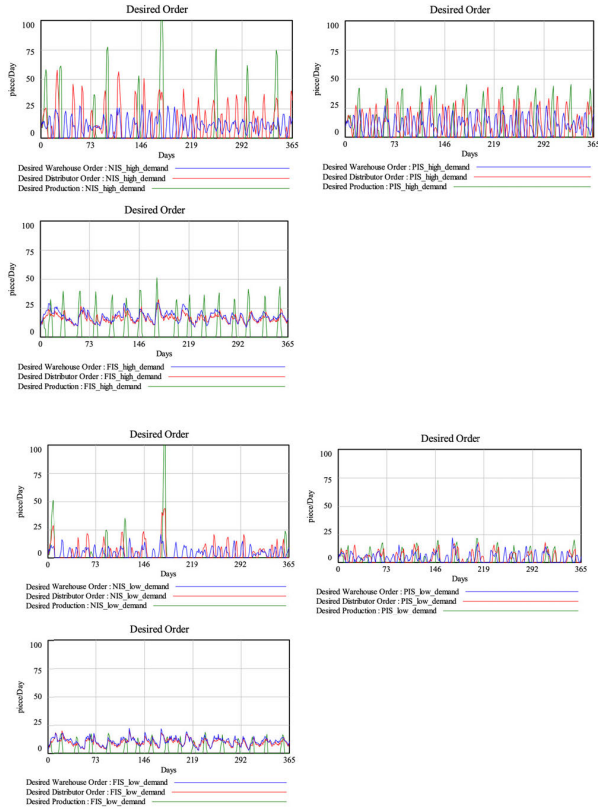


FIGURE 17. Mitigation of the bull whip effect in high demand and low demand.

TABLE 6. Parameters for SD model in different profit scenarios.

Parameter	Value	Unit
T	365	day
d^t	$G \sim (5, 1.5)$	piece/day
$\tilde{\lambda}_p, \forall p \in P$	2	day
$\beta_p, \forall p \in P$	2	day
$\chi_p, \forall p \in P$	2	day
L	5	day
$\alpha_p, \forall p \in P$	5	day
$\eta_p, \forall p \in P$	1	day
τ_m	1	day
π_e^{high}	150	cu/piece
π_d^{high}	120	cu/piece
π_m^{high}	90	cu/piece
π_e^{low}	50	cu/piece
π_d^{low}	40	cu/piece
π_m^{low}	30	cu/piece
ϕ_e	5	cu/piece/day
ϕ_d	5	cu/piece/day
ϕ_m	2	cu/piece/day
φ_e	10	cu/piece/day
φ_d	5	cu/piece/day
φ_m	2	cu/piece/day

2) PROFIT MARGIN AND INVENTORY COST

The settings of products with different profit margins are presented in Table 6 and the results are summarized in Table 7.

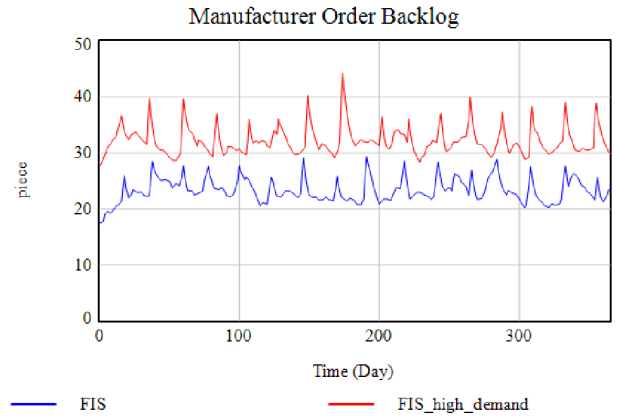


FIGURE 18. Manufacturer order backlog in high demand scenario.

TABLE 7. EVA comparison in different profit scenarios.

High Profit	NIS (cu)	PIS (cu)	FIS (cu)	↑ NIS-PIS	↑ PIS-FIS
E-Commerce Platform EVA	246766	250466	265713	1%	6%
Distributor EVA	94212.8	142594	567094	51%	298%
Manufacturer EVA	-20987.6	40211.8	328066	292%*	716%
Medium Profit	NIS (cu)	PIS (cu)	FIS (cu)	↑ NIS-PIS	↑ PIS-FIS
E-Commerce Platform EVA	123462	125752	137329	2%	9%
Distributor EVA	35861	53224	469687	48%	782%
Manufacturer EVA	-54297	-2776	258361	95%*	9,408%*
Low Profit	NIS (cu)	PIS (cu)	FIS (cu)	↑ NIS-PIS	↑ PIS-FIS
E-Commerce Platform EVA	-8786.85	-5771.06	9728.15	34%*	269%*
Distributor EVA	-55186.3	-17215.2	143644	69%*	934%*
Manufacturer EVA	-117074	-28464.5	68396.5	76%*	340%*

*ABS method is used to get the percentage.

While different inventory cost scenarios and the corresponding results are presented in Table 8 and Table 9, respectively.

For high margin products, the impact of information sharing on each party remains similar. However, when the margin is low, the downstream party benefits significantly from shared demand information since better planning would compensate the low profit. Inventory cost also plays an important

TABLE 8. Parameters for SD model in different inventory cost scenarios.

Parameter	Value	Unit
T	365	day
d^t	$G \sim (5, 1.5)$	piece/day
$\tilde{\lambda}_p, \forall p \in P$	2	day
$\beta_p, \forall p \in P$	2	day
$\chi_p, \forall p \in P$	2	day
L	5	day
$\alpha_p, \forall p \in P$	5	day
$\eta_p, \forall p \in P$	1	day
τ_m	1	day
π_e	100	cu/piece
π_d	80	cu/piece
π_m	60	cu/piece
ϕ_e^{high}	7	cu/piece/day
ϕ_d^{high}	7	cu/piece/day
ϕ_m^{high}	3	cu/piece/day
ϕ_e^{low}	3	cu/piece/day
ϕ_d^{low}	3	cu/piece/day
ϕ_m^{low}	1	cu/piece/day
φ_e	10	cu/piece/day
φ_d	5	cu/piece/day
φ_m	2	cu/piece/day

role in changing the dynamics among the three parties. While the inventory cost is high, the distributor becomes the biggest winner when the demand information is shared. On the other hand, the manufacturer could gain significantly with even partially shared information when the inventory cost is low.

In a nutshell, the more transparent the information flow is, the more the value could be created in the entire supply chain. However, the value generated by sharing information is not equally distributed among the supply chain participants and such distribution varies given different product characteristics (e.g. popularity, profit, and inventory cost). The upstream supply chain parties, the victim of the bull whip effect, gain the most from a transparent information flow in most cases. The complexity is that the downstream party, which plays the most important role in sharing the information, reaps the least from information sharing or even gets backfired in certain aspects. In particular, the numerical example and sensitivity analysis reveal that, in terms of backlog order, partial information sharing performs better than full information sharing for the E-Commerce operator and sharing information can hurt the overall EVA of the platform when the demand is low. This observation provides significant implications for enhancing supply chain collaboration. While practitioners well accept the idea that information sharing is beneficial, understanding the dynamics of the benefit distribution could help different supply chain parties to better form a strategic partnership by negotiating the profit and cost redistribution. Another implication from the sensitivity analysis is that fully sharing information may not always be necessary since partially shared information could already achieve great improvements in certain scenarios. Practitioners should

TABLE 9. EVA comparison in different inventory cost scenarios.

High Inventory Cost	NIS (cu)	PIS (cu)	FIS (cu)	↑ NIS-PIS	↑ PIS-FIS
E-Commerce Platform EVA	96418.9	100767	122422	5%	21%
Distributor EVA	-19880.3	36704.9	338786	285%*	823%
Manufacturer EVA	-142840	-16161	175812	89%*	1188%*
Medium Inventory Cost	NIS (cu)	PIS (cu)	FIS (cu)	↑ NIS-PIS	↑ PIS-FIS
E-Commerce Platform EVA	123462	125752	137329	2%	9%
Distributor EVA	35861	53224	469687	48%	782%
Manufacturer EVA	-54297	-2776	258361	95%*	9,408%*
Low Inventory Cost	NIS (cu)	PIS (cu)	FIS (cu)	↑ NIS-PIS	↑ PIS-FIS
E-Commerce Platform EVA	141560	143928	153019	2%	6%
Distributor EVA	58906.9	88674.2	371951	51%	319%
Manufacturer EVA	4778.64	27908.3	220651	484%	691%

evaluate the cost and obstacles for enabling full information sharing and may start with partial sharing.

V. CONCLUSION

In this study, we have addressed a fundamental topic in SCM – information sharing – engaging an innovative measurement method: VBM. Three information sharing scenarios have been analyzed in a trendy supply chain environment in which inventory turnover ratio is high and the information sharing cost is comparatively low. This study has developed three SD models to investigate the value created by E-Collaboration in a three-echelon E-Commerce supply chain with different collaboration strategies, namely, no information sharing, partial information sharing and full information sharing. These three models successfully reproduced the information distortion – the bullwhip effect, and confirmed previous findings in the literature that the bullwhip effect can be mitigated by proper information sharing. Although the benefit of information sharing in SCM has been studied and is well acknowledged, most previous quantitative studies measure the contribution of information sharing on the aggregated supply chain level. Our study unveils the impact of information sharing on

individual supply chain parties and bridges the gap in the literature. The study contributes to this stream of research by enriching the methodology, revealing counter-intuitive implications and guiding strategic E-collaboration.

Both the academic community and the industry can benefit from this research. First, an original contribution to supply chain performance is made. A uniformed supply chain performance metric is proposed to allow the comparison among the performance improvements of different supply chain partners due to shared information. With this performance metric, this study quantifies the value added by varying degrees of information sharing to different supply chain parties. This is the first attempt in the literature to quantify the impact of E-Collaboration from a VBM perspective and the model proposed can be extended to represent a multi-echelon supply chain. The method adopted in this work extends the application of VBM in SCM, to be more specific, in supply chain quantitative work. This method allows the impact on product order, inventory level and backlog order of different supply chain parties to be evaluated under the same metric. Second, evaluating the impact on different supply chain parties have led us to counter-intuitive insights. The results of the numerical examples revealed that although information sharing would benefit the entire supply chain, the downstream supply chain partner's rewards may be marginal or even negative when more information is shared. New findings show that value creation by E-Collaboration information sharing can be tremendously different among supply chain partners. The EVA boost reaped by the manufacturer is about 1000 times more than the retailer's gain under full information sharing. Furthermore, a counter-intuitive finding showed that the overall value-added could be significantly higher in the scenario of full information sharing when compared with that of partial information sharing. This leads to a dilemma in practice that a downstream supply chain partner would not wish to join an E-collaboration even though it is beneficial to the whole supply chain. Third, related to the second point, the tool devised in this study and the profound practical insights generated from the analysis would facilitate industry practitioners to form a strategic partnership that could sustain the E-collaboration. The counter-intuitive findings may help to identify the incentives and obstacles of current E-collaboration while the proposed SD model provides supply chain participants with a powerful tool to gauge the value of information sharing, which is a good reference to developing allied strategies aiming at mutual benefits. It is hoped that the insights provided in this study would guide practitioners to form win-win supply chain partnerships and therefore enhance supply chain collaboration in the long run.

Regarding future research, the work could be extended with the following enhancements: 1. Consider the full financial aspect of the EVA formulation; 2. Conduct case studies using empirical data and perform comparisons; 3. Tailor the model for specialized supply chains in which the value of information is amplified (e.g. cold chain).

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