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Information sharing in a sustainable supply chain

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ABSTRACT

Whilst information sharing is frequently cited as being the key to reducing supply chain cost, one may wonder if this claim holds true for sustainable supply chains. This paper addresses this gap in the literature by introducing information sharing in a two level sustainable supply chain model. Two dimensions of sustainable practices (environmental and social cost) have been quantified in the inventory model of this supply chain. An optimal shipment size and buyer's price are determined mathematically for the case of with- and without-sharing-information. It was observed that information sharing results in better annual profit with a drop in buyer's price. A sensitivity analysis of environmental costs to this enhancement in profit/price is carried out and some important managerial implications are outlined.

1. Introduction

The performance of supply chains have essentially depended on their level of coordination. Stakeholders in a supply chain have traditionally been ordering based on the size of demand from their downstream firms in order to minimize the impact of bullwhip effect. The current use of technology (e.g. ERP) fosters these partners in a supply chain to depend on electronic data interchange (EDI) to mitigate the impacts of demand variability. This exchange of information not only boosts the service level but also reduces the cycle time of a supply chain. The resulting reduction in the annual cost and inventories of the supply chain would be seen as a win-win situation for all the stakeholders involved. The level of these benefits would also depend on the structure and operational characteristics of a supply chain.

The new global reality that has emerged from the latest economic crisis calls for supply chains to be leaner and cost effective. In addition, and due to stricter regulations and increased legislative pressures, companies need to effectively integrate environmental concerns and green practices into their regular business including logistics and supply chain operations. The integration of sustainability within SCM is, therefore, emphasized in almost all industries and government operations. This, however, requires the collaboration of all stakeholders including supplier and customers.

The impact of information sharing on the performance of the supply chains has been an important issue in literature – Lee et al. (2000), Moinzadeh (2002), and Hussain et al. (2012). Whilst information sharing is frequently cited as being the key to reducing cost, there has been little research to investigate its value in a sustainable supply chain although sustainability is acknowledged as a major competitive priority. Managers are always keen to identify ways to successfully meet social and environmental targets and develop relevant tools that are economically viable – Winter and Knemeyer (2013).The relationship with suppliers tends to encompass the concern for social and environmental issues and exchange of information related to day-to-day tactics and policies related to material flow – Vachon and Klassen (2006). Though Lee et al. (2000) clearly mentioned that information sharing has a great value for supply chains but their significance has yet to be explored for a sustainable supply chain.

This paper models the impact of information sharing in a two-level socially/environmentally sustainable supply chain. The paper is organized as follows: a review of literature is presented in Section 2. A mathematical model is developed in the next three sections. Section 6 presents numerical analysis and discussion while the managerial implications and conclusions are presented in the last two sections.

2. Literature review

The literature on sustainability has mostly focused on environmental impacts while some researchers have put together the environmental, economic and social impacts to form the widely known triple bottom line perspective – Hacking and Guthrie (2008). Herva and Roca (2013) added institutional impact to this methodology while Ilskog (2008) recommended measuring technical impact also. Linton et al. (2007) argued that

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sustainability in supply chains should be moved from optimization of environmental factors to consideration of the entire supply chain, i.e. production, consumption, customer service and disposal of products.

A little focus has been put on the social dimension of sustainability in inventory modeling, till date. For example, Bouchery et al. (2012) developed a sustainable order quantity (SOQ) model that calls for a multi-objective criterion to set economic, environmental and social tradeoffs by taking into account the different regulatory pressures. They suggested an interactive procedure that allows the decision maker to quickly identify the best options among different alternatives. Battini et al. (2014) incorporated sustainability in EOQ modeling by considering environmental and social dimensions jointly in delivery operations. They accounted for various costs of transportation (i.e. congestion, accidents, roadway facility), warehousing and waste disposal to show that the proposed criteria helps practitioners to change their purchasing strategy and transportation modality more rapidly, with a clear economical convenience in adopting the intermodal transportation. Toptal et al. (2014) defined social cost to be the cost of unit emission reduction, in an EOQ model. They studied various investment opportunities to reduce carbon emission and found that social cost becomes very high as the policy parameters are tightened under different regulatory policies.

Ahi and Searcy (2013) identified 22 definitions of green supply chain management and 12 definitions for sustainable SCM through a systematic literature review. The reader is referred to Srivastava (2007), Seuring and Müller (2008), Mollenkopf et al. (2010), Gold et al. (2010), Carter and Easton (2011) and Sarkis et al. (2011) for similar reviews on sustainability.

The notion of information sharing is not new. It is believed in the modern industry that supplier is better off with information sharing while a retailer would need some incentives to share his cost and demand information. Nonetheless, the benefits of information sharing cannot be disregarded. For example

Wu and Edwin Cheng (2008) state that: "*Information sharing allows Wal-Mart to outsource much of its inventory planning to suppliers who become responsible for monitoring inventory levels, planning replenishment, and suggesting new ideas to improve throughout. At Dell, sales information cascades back several tiers to make the entire supply chain more efficient and responsive, enabling Dell to operate with only four days of inventory supply*".

Lee et al. (2000) is probably the first one to analytically assess the impact of this coordination. They showed that the magnitude of reduction in cost and inventory levels would be higher if the demand is highly correlated and lead time is longer. Yu et al. (2002) illustrated the benefits of information sharing in a decentralized supply chain partnership between retailer and manufacturer. Cheng and Wu (2005) generalized the work in Lee et al. (2000) and Yu et al. (2002) and showed that inventory level and the total cost of a supply chain decrease with in an increase in the level of information sharing.

Zhao et al. (2002) simulated the coordination of a single capacitated supplier and four retailers with different patterns of uncertain demand. Moinzadeh (2002) developed a supply chain for a single supplier and multiple retailers where demand at each retailer follows a Poisson distribution. He demonstrated that information sharing for the two stakeholders is only beneficial with longer lead times and smaller number of retailers.

Li et al. (2005) analyzed twelve information models to assess the value for information sharing in supply chains. Sucky (2006) developed a bargaining model for a single supplier and single buyer where the buyer shares asymmetric information about its cost structure while it has the power to impose its own optimal policy. Byrne and Heavey (2006) found that information sharing is advantageous all the echelons almost equally and that the more capacitated systems benefit to a larger extent from improved information sharing. Zhang and Zhang (2007) quantified the trade-off of implementing the demand information sharing strategy in a supply chain and found that the successful supply chains were those with high demand variance, low demand correlation and without an intermediate tier.

Esmaeili and Zeephongsekul (2010) presented several models for the asymmetric information exchange to describe how incentives could be introduced in these Stackelberg models to make echelons to share information. Inderfurth et al. (2013) showed that information sharing would be more beneficial if there is a reward for better informed echelon and a likewise punishment for a less informed echelon. Cannella (2014) used difference equations to evaluate the role of information exchange in a periodic review order-up-to inventory policy in a four-echelon supply chain. They found that order smoothing in a collaborative supply chain would be beneficial for all the echelons.

Salameh and Jaber (2000) have provided a new dimension to the literature in inventory management by featuring the importance of screening in an EOQ model. This model has recently been extended for numerous practical situations, e.g. Khan et al. (2011a, 2012, 2014). A review of some early extensions of this model can be found in Khan et al. (2011b). Khan et al. (2014) had discussed the impact of screening errors and learning in production in a simple two level supply chain model of defective items. Besides, Andriolo et al. (2015) revisited economic lot sizing problem to show that haulage space shared by two buyers is highly beneficial both for cost and emission reduction. Moreover, Andriolo et al. (2014) have recently analyzed 219 selected articles to highlight the evolution of EOQ theory, reflecting the development of industrial systems over the past century. They showed that it is virtually impossible for a single model to perfectly describe the real industrial situation under study.

This paper fills a gap in literature by (i) introducing information sharing and quality to sustainable order quantity modeling, and (ii) integrating the parameters of social and environmental sustainability to coordination in a two level supply chain.

3. Model description

Considering the above research in information sharing/exchange in supply chains, the base model in Khan et al. (2014) will be employed in this paper to fill the following gaps in this important area:

1. It integrates environmental and social aspects as a measure of price and quality in a supply chain model of defective items.
2. It highlights the impact of information sharing in this model.
3. It highlights the significance of the environmental and social costs for supply chain's profit.

A sustainable supply chain may have several measures of quality such as conformance to features, pollution content, energy used, possibility of remanufacture and disposal methods etc. (Saadany et al. 2011). This makes it virtually impossible for an operations manager to have an accurate estimate of quality. This paper, for the sake of simplicity, assumes a general fraction of defectives to be a cumulative/single representative of quality.

The emissions are usually expressed as a function of the production rate, equipment speed and energy consumption (Jaber et al. 2013). It has also been modeled as a function (linear, convex or concave) of the weight of a transport vehicle (Elhedhli and Merrick, 2012). This weight is proportional to the buyer's demand. Including capacity of a vehicle and the mode of transportation will complicate the relationship even further. All of this constitutes a cost of every weight-unit of the greenhouse gases. Once these emissions cross the allowed limit, a company incurs a penalty cost. The European Union Emission Trading System (EU-ETS) depends on a ‘cap and trade’ system where companies are penalized for crossing their cap whereas they can trade their allowances if their emissions remain below the specified limit.

On the other hand, integrating social dimension of sustainability in supply chains poses a significant challenge. Most of the data related to this dimension would either be unavailable or complex. For example, consider a company that is interested in improving motivation in its workers through an ergonomic design of their shop floor. The design requirements identified for this initiative would be too specific for that company while the downstream buyer may not acknowledge this investment. The same would be true for other social indicators such as equity, education, health, security etc. (Hutchins and Sutherland, 2008).

The cost of all the above indicators (environmental and social) may be in a complex mathematical relationship with order quantity. For the sake of simplicity of analysis, this paper assumes this relationship to be linear.

The following notations are used in the mathematical model:

n	=	Number of shipments from the vendor to the buyer in a production cycle (decision variable)
Q	=	Size of shipment from the vendor to the buyer (decision variable)
p	=	Buyer's revenue per unit sold (decision variable)
v	=	Vendor's revenue per item shipped
T	=	Time between successive shipments (years)
d	=	Buyer's unit screening cost ($)
x	=	Buyer's screening rate (units/year)
E_b	=	Environmental cost parameter for buyer
E_v	=	Environmental cost parameter for vendor
S_b	=	Social cost parameter for buyer
S_v	=	Social cost parameter for vendor
D	=	Demand for the vendor (units/year)
P	=	Vendor's production rate (units/year)
c	=	Vendor's production cost per unit time ($/year)
F	=	Buyer's fixed transportation cost per shipment ($)
g	=	Buyer's transportation cost per unit of the product shipped ($)
A_v	=	Vendor's fixed ordering or setup cost ($/year)
A_b	=	Buyer's setup cost ($)
h_v	=	Vendor's unit holding cost for the product ($/item/year)
h_b	=	Buyer's unit holding cost for the product ($/item/year)
γ	=	A parameter for demand function
θ	=	A parameter for demand function
φ	=	A parameter for demand function
q	=	Vendor's fraction of non-defective items in a lot

4. Mathematical model

Using the base model from Khan et al. (2014), it is assumed that a single vendor and a single buyer work without coordination to optimize their inventory policy. The buyer screens out vendor's defective items while fulfilling their demand. The vendor's inventory profiles are depicted in Figs. 1 and 2.

Assume buyer's demand is a function of buyer/retailer's selling price and vendor's quality; Banker et al. (1998) as

$$D(p, q)=\gamma - \theta p + \varphi q \tag{1}$$

The vendor's quality would be taken as a fixed parameter in this model. The vendor has to pay a tax for emissions caused during production; Jaber et al. (2013), i.e.

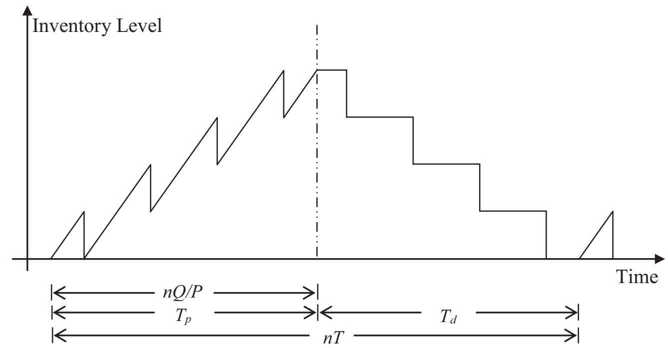

Fig. 1. Vendor's inventory level in a cycle with time.

$$EC_v = nE_vQ$$

Similarly, vendor's social cost based on weighted sum of labor, health services, safety and philanthropy (Hutchins and Sutherland 2008), is

$$SC_v = nS_vQ$$

The total inventory with the vendor in a cycle, as shown in Fig. 2, is

$$I_v(Q, n, p) = \frac{n^2Q^2}{2P} + \frac{nQ^2(n-1)(P - D(p, q))}{PD(p, q)} - \frac{n(n-1)Q^2}{2D(p, q)}$$

$$I_v(Q, n, p)=\frac{nQ^2}{2D(p, q)}\left\{(n-1) - (n-2)\frac{D(p, q)}{P}\right\} \tag{2}$$

Therefore, vendor's total cost in a cycle is the sum of setup, carrying and production, emission and social costs:

$$C_v(Q, n, p) = A_v + \frac{h_vnQ^2}{2D(p, q)}\left\{(n-1) - (n-2)\frac{D(p, q)}{P}\right\} + \frac{ncQ}{P} + nQ(E_v + S_v)$$

And their annual cost would be estimated by using $T_v = n(1 - q)Q/D(p, q)$

$$AC_v(Q, n, q) = \frac{D(p, q)A_vM}{nQ} + \frac{h_vQM}{2}\left\{(n-1) - (n-2)\frac{D(p, q)}{P}\right\} + \frac{cMD(p, q)}{P} + D(p, q)(E_v + S_v)M$$

Vendor's annual profit would be the difference between annual sales revenue and the above annual cost, i.e.

$$\pi_v(Q, n, p) = (v - \frac{A_v}{nQ})MD(p, q) - \frac{h_vQM}{2}\left\{(n-1) - (n-2)\frac{D(p, q)}{P}\right\} - (\frac{c}{P} + E_v + S_v)MD(p, q) \tag{3}$$

For a given number of supplies per cycle, vendor's production lot size would be calculated as

$$Q = \sqrt{\frac{2A_vD(p, q)}{nh_v\{(n-1) - (n-2)\frac{D(p,q)}{P}\}}} \tag{4}$$

On the other hand, the buyer bears taxes induced by the emissions in transportation and storage. Besides, he endures social cost for their workers too. Therefore, buyer's total cost in vendor's one cycle is the sum of ordering, purchase, carrying, screening,

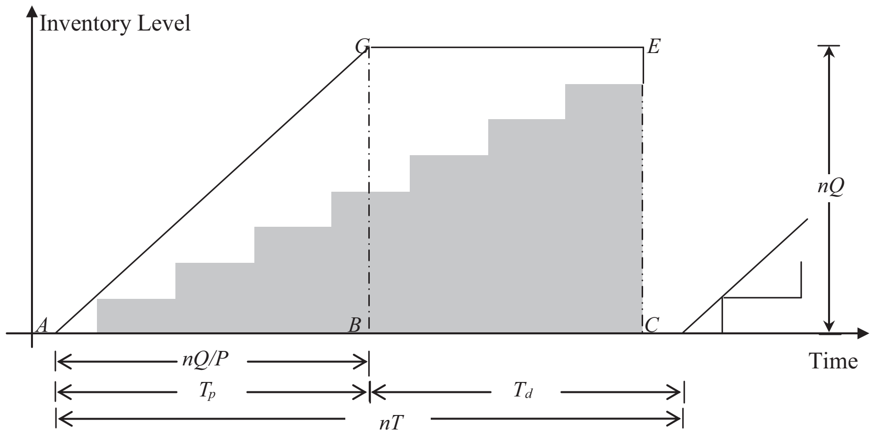

Fig. 2. Accumulation and supply of vendor's inventory in a cycle.

transportation, emission and social costs, i.e.:

$$C_b(p) = A_b + nvQ + nh_b\{\frac{Q(1-q)T}{2} + \frac{qQ^2}{x}\} + ndQ + n(F + gQ) + nQ(E_b + S_b)$$

And their annual cost would be estimated by using $nT = nQ(1-q)/D(p, q)$

$$AC_b(p) = \frac{D(p, q)MA_b}{nQ} + (d + v)MD(p, q) + h_b\left\{\frac{Q(1-q)}{2} + \frac{qQMD(p, q)}{x}\right\} + \frac{FMD(p, q)}{Q} + gMD(p, q) + MD(p, q)(E_b + S_b)$$

Similarly, buyer's annual profit would be the difference between the annual revenue it receives by selling products to customers, and the above annual cost

$$\pi_b(p) = (p - v - d - g - E_b - S_b)MD(p, q) - \frac{MD(p, q)}{Q}\left(\frac{A_b}{n} + F\right) - h_bQ\left\{\frac{(1-q)}{2} + \frac{qMD(p, q)}{x}\right\} \quad (5)$$

For a given lot size and number of supplies per cycle, the buyer sets the price per item as

$$p = \frac{1}{2}\left\{\frac{\gamma + \varphi q}{\theta} + (v + d + g + E_b + S_b) + \frac{1}{Q}\left(\frac{A_b}{n} + F\right) + \frac{h_bQq}{x}\right\} \quad (6)$$

It should be noted that the buyer will set this price without sharing this information with the vendor.

5. Information sharing

In case of information sharing, the buyer and vendor may share information about possible yield losses, output uncertainty, capacity shortages, equipment problems, quality issues and or insufficient stocks. This would result in joint optimization of the profit function depicted in Eqs. (3) and (5) above. In other words, they would share the joint profit; Esmaeili et al. (2009), such that

$$Z(Q, n, p) = \pi_v + \pi_b \quad (7)$$

$$Z(Q, n, p) = \left(v - \frac{A_v}{nQ}\right)MD(p, q) - \frac{h_vMQ}{2}\left\{(n-1) - (n-2)\frac{D(p, q)}{P}\right\} - \left(\frac{c}{P} + E_v + S_v\right)MD(p, q) + (p - v - d - g - E_b - S_b)MD(p, q) - \frac{MD(p, q)}{Q}\left(\frac{A_b}{n} + F\right) - h_bQ\left\{\frac{(1-q)}{2} + \frac{qMD(p, q)}{x}\right\}$$

$$Z(Q, n, p) = \left(p - \frac{c}{P} - d - g - E_b - S_b - E_v - S_v\right)MD(p, q) - \frac{MD(p, q)}{Q}\left(\frac{A_b + A_v}{n} + F\right) - \frac{Q}{2}\left[h_vM\left\{(n-1) - (n-2)\frac{D(p, q)}{P}\right\} + h_b\left\{(1-q) + \frac{2qMD(p, q)}{x}\right\}\right] \quad (8)$$

The above equation can be used to determine an optimal size of shipment in information sharing (coordinated) scheme, as

$$Q = \sqrt{\frac{2MD(p, q)\left(\frac{A_b + A_v}{n} + F\right)}{h_vM\{(n-1) - (n-2)\frac{D(p,q)}{P}\} + h_b\{(1-q) + \frac{2qMD(p,q)}{x}\}}} \quad (9)$$

The optimal number of shipments would be calculated through iteration and with the above shipment size, the optimal price of an item in the coordinated scheme would be

$$p = \frac{1}{2}\left\{\frac{\gamma + \varphi q}{\theta} + \left(\frac{c}{P} + d + g + E_b + S_b + E_v + S_v\right) + \frac{1}{Q}\left(\frac{A_b + A_v}{n} + F\right) + \frac{h_bqQ}{x}\right\} - (n-2)\frac{h_vQ}{2P} \quad (10)$$

Comparing this price with the one in Eq. (3), one should notice that the price of an item goes down with information sharing. The magnitude of this difference would be

$$\Delta p = \frac{1}{2}\left\{\left(v - \frac{c}{P} - E_v - S_v\right) + (n-2)\frac{h_vQ}{P} - \frac{A_v}{Qn}\right\} \quad (11)$$

This difference in price will contribute in improving the annual profit of the supply chain with information sharing.

6. Numerical analysis

Consider a two-level vendor-buyer supply chain where a vendor's lots have some defective items which are screened out by the

Table 1
Input data for numerical example.

P	C	x	A_v	A_b	h_v	h_b	D	F	G	E_v	E_b	t_v	t_b
3200	100,000	175,200	400	25	40	50	0.5	25	2	5000	8000	0.0085	0.0010
				S_v	S_b	v	θ	φ	Q				
				0.426	0.668	500	0.75	100	0.9				

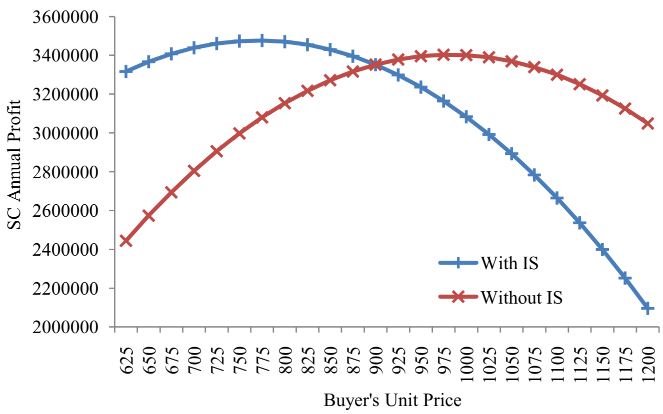

Fig. 3. Supply chain's annual profit with buyer's unit price.

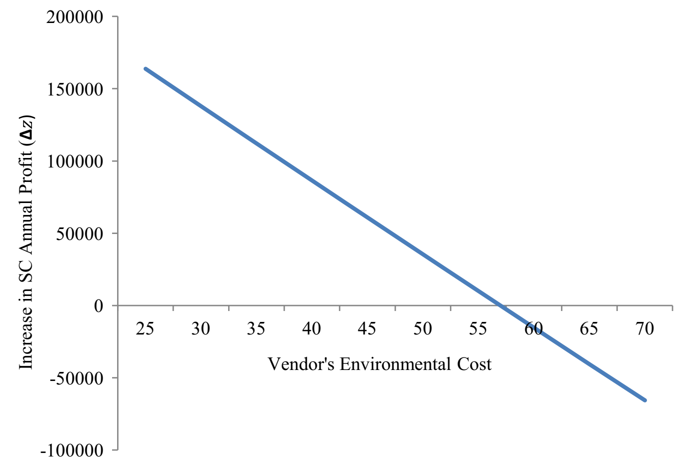

Fig. 4. Increase in annual profit with information sharing.

buyer – Salameh and Jaber (2000). In the following examples, the benefits of their information sharing and coordination would be illustrated. Input data for these examples is borrowed from Jaber et al. (2013), Battini et al. (2014) and Hutchins and Sutherland (2008) (Table 1):

In case of no information sharing, the two stakeholders independently determine the selling price, number of deliveries per cycle and the size of shipment. Fig. 3 shows how the total annual profit of the supply chain varies with buyer's unit price. It should be noticed that the total profit is concave with buyer's price. This figure highlights the value of information sharing in terms of the increase in annual profit. This increase comes along with a decrease in the buyer's unit price shown in Eq. (11). In this case, the two stakeholders jointly determine the size of shipment, number of shipments per cycle and the buyer's unit price.

Many industries have embarked on reengineering efforts to improve the efficiency of their supply chains. The goal of these programs is to better comply with environmental and social laws and to share all that information with network of suppliers and distributors. These re-engineering efforts have resulted in more coordination and cooperation through information sharing between different tiers in a supply chain in the form of sustainable practices, emphasis on logistical issues when designing a product (e.g., delayed differentiation and postponement), modular product and process design, agile supply networks. Investment in IT however, has resulted in the availability of more information on channel activities to decision maker(s), who, in turn, must find ways of incorporating them in their day-to-day decisions to achieve competitive advantage and better comply with global and local standards of sustainable practices. Walmart and Dell both are implementing sustainable practices across their supply chains to provide good illustration of information sharing with their suppliers.

In Fig. 4, an attempt has been made to evaluate the range of buyer's unit price for which the decreasing price remains beneficial for the coordination in supply chain. Eq. (11) was employed to study this behavior. It was observed that at low estimates of vendor's environmental costs, the price difference of the two schemes remains high and boosts the worth of information sharing. This is a lucrative situation for both the stakeholders where lesser harm is caused to the environment at a higher profit while the consumers also have to pay a lower price. As the estimate of environmental cost starts taking higher values, information sharing loses its value and the two schemes would result in the same annual profit at a certain unit price.

To enhance the results of this research, an experiment was designed for 1000 examples. For each example, a random set of input parameters was generated, and the output in terms of supply chain profit was optimized and recorded. To generate the random input parameters, the following ranges of the dataset were employed.

Vendor's environmental cost (E_v)	4500–9000
Buyer's environmental cost (E_b)	4500–9000
Vendor's social cost (S_v)	0.000–1.000
Buyer's social cost (S_b)	0.000–1.000

The results from the analysis of variance for the supply chain profit are shown in Table 2. The degree of significance of each factor is represented in Table 2 by its p–value (less than 0.05). The table shows that the environmental cost parameter for both the stakeholders has a significant effect on the overall profit of the supply chain. The rationale is that the more deviant these parameters are from the regulated ones the worse impact they would have on the overall profit. Thus, the supply chain would harm not only the environment but their profit as well. This behavior is also depicted in Fig. 5.

Table 2
Significance of the input parameters for Z.

	Coefficients	*Standard Error*	*t Stat*	*p–value*
Intercept	3745408.60	18230.73	205.44	0.00
E_v	–43.04	0.10	–413.74	0.00
E_b	–5.16	0.01	–382.71	0.00
S_v	–5076.35	27.68	–183.42	0.00
S_b	–5053.82	27.49	–183.82	0.00

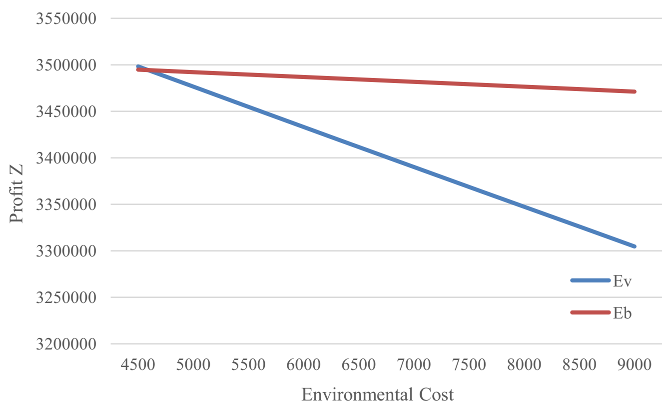

Fig. 5. Impact of environmental cost on supply chain profit.

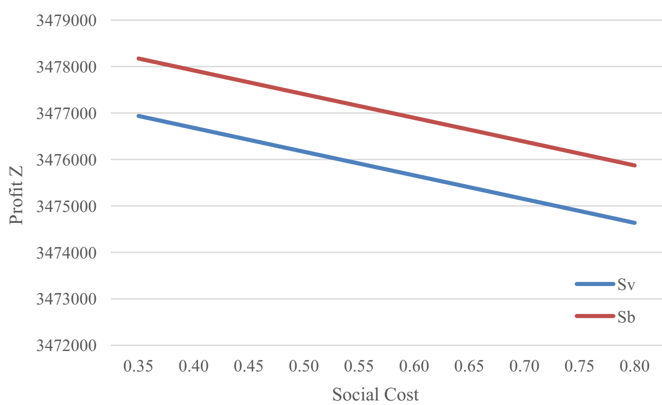

Fig. 6. Impact of social cost on supply chain profit.

The table also shows that the parameters of social cost have a significant impact on the overall profit of the supply chain. The rationale is that the lesser attention on the social dimension of the organization would eventually cut down the overall profit. This pattern is also depicted in Fig. 6 for the two stakeholders of the supply chain.

Figs. 5 and 6 show how the supply chain profit responds to varying estimates of environmental and social costs of the two stakeholders. Fig. 5 depicts that the higher estimates of environmental cost of the two stakeholders have an adverse impact on the profit and if not maintained well, these costs may make the supply chain profit critically low. It should be noticed that the profit is modeled to be linear in these estimates of environmental costs (Eq. (8)) though the estimates themselves may have a non-linear relationship with their cost components such as production rate and haulage space etc. (Jaber et al., 2013).

Fig. 6 describes a similar linear response of the profit against variation in the estimates of social cost (Eq. (8)). The difference or gap between two lines comes from the choice of numerical estimates thus making the buyer (retailer) more responsible for components of social cost such as equity, education, health and security etc. (Hutchins and Sutherland, 2008).

Therefore, one can see that profitability and sustainability are often at odds with each other. They are typically managed with distinct budget and vision by mainly focusing on short term targets. However, if sustainability were viewed through the lens of risk to business continuity, the case for a longer-term approach would be easier to make. Supply chains would need to assess the trade-off between sustainability and the associated costs.

It should be noticed that mature supply chains, which are already using green technology, can clearly benefit from information sharing since their environmental cost will be low. On the contrary, evolving supply chains, where sustainable practices are less observed, the use of information sharing cannot be beneficial if environmental cost is too high. There is a dilemma here because sustainable practices will have a cost associated with its implementation, and whilst it may deal with the problem of carbon footprint very well, but supply chain may not benefit from information sharing. In contrast, information sharing is clearly of great value when the environmental cost is smaller. So, with the increasing drive to further reduce carbon footprint, there should be an increasing justification for adopting and investing in information sharing.

7. Managerial implications

The model in this paper is an important addition to the line of research in Salameh and Jaber (2000) as it incorporates environmental and social costs to a two level chain model. It should be noticed that there is a growing concern in the industry about the measures of sustainability such as the parameters of environmental and social costs. These parameters are an important part of the modern sustainable framework for any supply chain. A wise choice of these parameters would establish the objectives of a supply chain to minimize its impact to workers, communities and the environment. The paper would help managers make smarter decisions based on the specific environmental, health and safety issues in their industry. This would result in a diligent program to engage all the stakeholders in forming and reviewing the most sustainable coordination scheme.

Whilst the impact of information sharing on the bullwhip (demand amplifications) has been extensively studied in literature (Lee et al., 2000; Moinzadeh, 2002; Hussain and Saber, 2012), there has been little research to investigate the value of information sharing in a batched model although batching is acknowledged as a major cause of amplification. This enlightens the very fact that information sharing is the basis of developing and maintaining a strong relationship which is essential for managing the environmental and social impacts of a supply chain.

Managing environmental and social issues have been a challenge for many industries as sustainable practices are becoming a legal demand by consumers. The specific focus on certain impacts would vary among companies. It would essentially depend on the products and/or services in question. For example,

- One of the greatest priorities at Nike has been to improve the working conditions for workers in its supply chain.
- Ford has formed a supply chain sustainability group to align with their suppliers the issues related to greenhouse gas emissions management and human rights.
- Better Cotton Initiative (BCI) evaluates the impacts of cotton production worldwide. BCI tries to promote measurable improvements in the key environmental and social impacts of cotton cultivation worldwide.
- Chemical and pharmaceutical firms are required to disclose energy and water consumption figures and to use organically grown resources as well.
- Textile industries use extra enzymes to do laundry washing at lower temperatures with lesser amounts of water and chemicals. This initiative helps them improve the quality of the wastewater.
- The environmental concerns in supply chains of oil and gas industry would range from toxic waste, water pollution and deforestation to hazardous air pollutions.

Therefore, it would be crucial for supply chain managers in all the industrial examples above to carefully estimate their parameters of environmental and social costs to optimize their joint profit in Eq. (8). While making the supply chain economically viable, this would also bring their performance in line with regulatory, customer, and community expectations (Klassen and Vereecke, 2012)

8. Conclusions

This paper makes use of the model in Khan et al. (2014) to study the impact of environmental and social costs on the information sharing in a two level supply chain. The paper provides mathematical formulation for the reduction in buyer's unit price and the enhancement in the supply chain's annual profit by virtue of information sharing.

It was observed that information sharing results in better annual profit. This gain in profit depends on the buyer's unit price and the parameters for environmental and social cost. The paper suggests that sharing information may not be beneficial if these parameters go beyond a limit.

The paper can be extended by elaborating more on the specific environmental and social issues as well as making quality a decision variable in the supply chain model. One could also investigate the impact of waste and repairable defectives.

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