Two layer supply chain with one retailer and two suppliers under random demand, supply disruption and promotional e ort

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Abstract

This paper studies the coordination issue of a supply chain consisting of one retailer and two suppliers, one is main supplier and another is backup supplier. The main supplier's yield is subject to disruption and the retailer faces a random demand. We determine the retailer's optimal ordering policy and the main supplier's production quantity that maximize expected pro t of the centralized supply chain. Numerical examples are given to gain some qualitative insights.

Keywords: Supply chain management; Random supply; Uncertain demand; Disruption.

1 Introduction

This paper studies the coordination issue of a supply chain among one retailer and two suppliers, one is main supplier and another is backup supplier under . Few researchers already have done important work in the area of random demand along with supply disruption. We are going to consider the supplier's random yield, along with supply disruption, during which the output of the production is zero in this research. Apart from this what we are trying to do new here is that we consider the e ect of promotional e ort in the supply chain along with the supplier's random yield and supply disruption. We also propose an overproduction risk sharing and buy-back contracts with a side payment for supply chain coordina-tion. Our work aims upon two areas of research: random yield with disruption and promotional e ort and buy back contracts in a supply chain with demand uncertainty.

In any production or logistics process random yield is somewhat a common issue. It is related to the fact that putting equal amount of input, the output of the production varies. Due to damage that occurs during transferring, any transportation process can also be viewed as random yield process. Some random yield process are for example, if the cost of tracking partial orders is high or the transportation costs are high, the supply contract may specify delivery in a single shipment with the uncertainty in delivery time, one can refer to the papers of H. Gurnani, R. Akella, and J. Lehoczky,(1996) ; in other situations, the manufacturer may agree to accept partial shipment of the order quantity like it is mentioned in K.Moinzadeh an H. L. Lee, (1989).

In the last few decades many researchers have done work in the area of random yield which is worth to mention. There is a widespread literature in the eld of random yield. Mukhopadhyay and Ma (2009) developed a single-period model to evaluate the optimal procurement and production decisions with uncertain demand and random yield of the used parts under three di erent cases. Gerchak and Grosfeld-Nir

(1998) analysed the trade-o between set-up cost and production cost when making batch production decisions, where both the random yield and random demand follow a general discrete distribution. He and Zhao (2012) investigated the ordering policy of the retailer, raw material planning decision of the supplier, and the optimal contracts for a three-level supply chain with random yield and demand.

Now apart from random demand, supply chain disruption has also caught the attention of the researchers. Industries across the world have experienced losses from a variety of disruptions; the major disruptions include massive oods, hazardous chemical explosions, industrial strikes, and extreme weather condition or natural calamity. When the supply chain (SC) reacts to these disruptions by implementing a mitiga-tion and recovery strategy, the main goals are to maintain or resume the continuity of the operation while meeting customer expectations and minimizing potential negative impacts. This complex optimization problem has motivated many researchers to study on supply chain disruption management (SCDM). A literature review by Ivanov et al. (2016) analysed quantitative studies that focused on reactive approach to face supply chain disruption. According to the authors, three basic risks to be considered are pro-duction, supply and transportation disruptions with common problems whether there are measure for recovery or without any.

As we have already mentioned that in this paper the two main areas of our research are random yield with disruption and promotional e ort and buy back contracts in a supply chain with demand uncertainty. Many researcher have worked on di erent kind of contracts. For example in the model of Guler and Bilgic (2009), they studied the coordination of an arbitrary number of suppliers with random demand and random yield and established the concavity of expected supply chain pro t and proposed two mixed type of contracts to coordinate the chain under forced compliance. Under the wholesale price contract, Keren (2009) analysed a two-tier supply chain, where a distributor facing a deterministic demand pro-cures a product from a producer confronting a random production yield. And an analytical solution to the distributor's ordering decision is derived when the production yield follows the uniform distribution. Li et al. (2012) extended and provided new results on the supply chain model with producer's random yield proposed by Keren (2009) . They derived analytic solutions of the supply chain decisions under generalized yield distribution.

Now we discuss about the promotional e ort in the supply chain. In recent times, several researchers have been working on the cooperative advertising policy in a manufacturer-retailer channel. This type of collaboration between two members of the supply chain can be de ned as nancial agreement in which manufacturer agrees upon to share cost of promotional e ort and o ers to bear either certain part or the entire advertising expenditure of his retailer. Advertising is one of the most powerful and major tools used by the companies to target large number of buyers and populations. It consists of impersonal forms of communication conducted through paid media under clear sponsorship. Advertising can be used to build up a long term image for a product or to embark quick sale Kotler,(2001). Battberg and Neslin (1989) have discussed about promotion e ects the sale to what extent. Krishnan et al.(2004) determined the promotional e ort to maximize the revenue and explained that promotional e orts may include anything starting from o ering free gifts to customer then price cuts , discounts in price, special services and many such more attractive incentives. Abad (2003) considred the ratiler's pricing and lot sizing policies under supplier's trade promotion. Kurata and Liu (2007) contemplated how a retailer reasonably decides upon the price discount promotion. Szmerekovsky and Zhang (2009) considered the pricing decisions and two-tire advertising levels between one manufacturer and one retailer where the customer demand depends on the retail price and advertisement by a manufacturer and a retailer. Xie and Wie (2009) and Xie and Neyret (2009) determined the optimal cooperative advertising strategies and equilibrium pricing in a two-echelon distribution channel.

Supply disruption along with promotional e ort is not considered by the above-cited literature on ran-dom yield. However, in practical reality, a supplier may be unable to satisfy the production order for a variety of reasons, such as equipment failures, damaged facilities, problems in procuring the necessary raw materials, and so forth. With more and more enterprises starting to realize that supply disruption severely a ects their ability to successfully manage their own supply chains, supply disruption manage-ment has received increasing attention. Many researchers have devoted much e ort to studying this issue. Hendricks and Singhal (2013) estimated the short-term e ects of supply disruption such as pro-duction or shipment delays on shareholder value. Taking into account the disruption frequency and the loss of market share, Pochard (2003) analysed the value and the bene ts of dual sourcing. Sarkar and Mohapatra (2009) considered the risks of supply disruption due to occurrence of super, semi super, and unique events and determined the optimal size of supply base. Since double marginalization J. Spengler (1950) will directly lead to ine cient performance of the supply chain, coordination of activities among the di erent members in the supply chain is necessary for the whole supply chain's e ective manage-ment. A great deal of e ort has been devoted to the research of the supply chain coordination issues. All kinds of popular contracts have been explored in the literature for the supply chain coordination, such as buy-back contracts or returns policies A. Roy et al. (2014),H. Emmons and S. N. Gilbert (1998) and S.Webster and S. K.Weng (2000), revenue sharing contracts Y. Gerchak and Y. Wang (2004) and G. P. Cachon and M. A. Lariviere (2005), wholesale price contracts M. A. Lariviere and E. L. Porteus (2001), risk sharing contracts C. L. Li and P. Kouvelis (1999), quantity discount policies C. Corbett and X. Groote (2000), quantity exibility contracts A. A. Tsay (1999), sales rebate contracts T. A. Taylor (2002), and so on. These explored a variety of other combined contracts and found which can be applied properly.

The rest of the paper is organized as follows: Section 2 explains the fundamental assumptions and notations and assumptions, Section 3 provides mathematical formulation and analysis of the model. In section 4 we have discussed some numerical examples,section 5 is dedicated to illustrate the sensitivity analysis,the last section i.e, section 6 is for to draw conclusion on the ndings of the paper.

2 Fundamental Notations and Assumptions

The following notations and assumptions are made to develop the proposed model:

2.1 Notation

(i) c_m = Production cost ($/unit) of the main supplier's.

(ii) c_b= Production cost ($/unit) per unit of the backup supplier.

(iii) c_u= Shortage cost ($/unit) per unit of the retailer.

(iv) s= Unit selling price (retail price) ($/unit) of the retailer.

(v) c_m = Marginal cost incurred due to event of disruption in supply.

(vi) v= Unit salvage value/return price ($/unit) of unsold goods of the retailer i provided by the manufacturer.

(vii) w_m= The primary suppler whole price($/unit).

(viii) w_b= The secondary suppler whole price($/unit).

(ix) p= the probability of disruption of yield.

(x) x= A part of demand quantity (units/month) during a period, which is a random variable following probability distribution.

(xi) f(x)= Probability density distribution function of x.

(xii) F (x)= Cumulative distribution function of x.

(xiii) L= The EPQ (economic production quantity) of the primary supplier (i.e., how many product to be produced by the primary supplier).

(xiv) Q= The EPQ (economic production quantity) of the secondary supplier (i.e., how many product to be produced by the secondary supplier).

(xv) Y = A random yield variable and positive support on [0,1] which satis es P fY = 0g = p and P f0 < Y 1g = $\int_0^1$ g(y)dy = 1 p = q.

(ix) g(y)= Probability density distribution function of y. Here g(y) is not probability density function unless p = 0.

(xvi) = Promotional/advertising e ort (units/month).

(xvii) D(x;)= Demand (units/month) which is a function of the promotional e ort.

(xviii) E_c(Q; L;)= Expected pro t ($/month) function of the chain in centralized model.

2.2 Assumptions

(i) The supply chain model is developed for a single period item.

(ii) The model associated with two-echelon supply chain comprising one retailer and and two suppliers.

(iii) The Demand rate of the chain is assumed to be the function of promotional e ort cost.

(iv) Among the two suppliers one is primary/main supplier and another is secondary/backup.

(v) Primary supplier is not reliable with cheaper wholesale price whereas secondary supplier is not reliable with expensive wholesale price.

(vii) The secondary supplier’s production has a perfect yield as secondary supplier can convert similar products in the inventory to satisfy the order. The chain is with buyback policy.

(viii) The lead time is negligible, and replenishment rate is instantaneously in nite but its size is nite.

(ix) This depicts the supply chain having o -shoring situation.

(x) The customer demand rate is partly dependent on promotional e ort and uncertain factors. So, it is a combination of a promotional e ort variable and an uncertain variable.

3 Mathematical Formulation and Analysis of the Model

In this model we have considered a two layer supply chain with two supplier and one retailer. In this two-echelon supply chain the primary supplier sells its product through one retailer. We consider that the retailer may face the some supply disruption. That is why there is another supplier who is known as secondary supplier. We assume that the secondary supplier’s production has a perfect yield, for example, the secondary supplier can convert similar or better products from his inventory to satisfy the order. There is a buyback policy between the supplier and the retailer. To ensure that each member of the chain has a positive pro t so we assume the following inequality

$c_b > c_{m>} > v$

$s > w_b > c_b$

$s > w_b > c_m$.

The retailer and the suppliers are two risk-neutral rms that are controlled by a centralized decision maker. The retailer incurs some promotional e ort cost to increase the di erent product sales on the market. So, the market demand is in uenced by the advertising expenditure incurred by the retailer that results in promoting the retail sales.

We de ne the demand function as D(x;) = x ( ), where x is a random variable that follows p.d.f f(x) and

$$1 \quad \frac{1+}{1} \qquad (1)$$

Here, is a decision variable (the e ort for promotional activities) and is a positive constant which is estimated from previous data by any curve tting method ; ( ) is an increasing function of because

$$( ) = \overline{(1+)^2} \quad 8 \quad 0:$$

Here (0) = 0 when ! 0 and ( ) ! when ! 1, which is maximum. Now, the cost of advertising or promotional e ort is

$$G( ) = k^{m} \qquad (2)$$

where k is a scale parameter and m is an elasticity parameter, and both are positive constants.

3.1 Centralized Supply Chain

In Centralized model of this system, both supplier and retailer make decision after consulting among themselves. Therefore, important strategies such as deciding on the optimal order quantity, the optimal production quantity and optimal promotional e ort are determined by the both supplier and retailer as a joint venture. The prime objective of the members of the chain is to maximize the integrated expected pro t of the system. To establish a performance benchmark, we rst analyse the optimal solution of an integrated supply chain. So, the expected integrated supply chain pro t in the centralized model is given by

$$E_C(Q; L;) = sE \min(X ( ); LY + Q) + vE(LY + Q \;\; X ( ))^+$$
$$c_u E(X ( ) \;\; Y L \;\; Q)^+ \quad c_b Q \quad c_m L \;\; G( ) \qquad (3)$$

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where = p + q. The rst term in (3) is the expected revenue from sales, the second term is the salvaged value, the third term is the opportunity cost due to the lost sales, forth and fth term are the production costs and last term related to promotional e ort.

From (3), the integrated supply chain's expected pro t function can rewritten as follows:

$E_c(Q; L;) = p$ ($\int_0^{Q/()}$ [sx ( ) + v(Q x ( ))]f(x)dx + $\int_{Q/()}^{1}$ [sQ c_u(x ( ) Q)]f(x)dx])

+ $\int_0^1 \int_0^{(Ly+Q)/()}$ [sx ( ) + v(Ly + Q x ( ))]f(x)dx

+ $\int_{(Ly+Q)/()}^{1}$ [s(Ly + Q) c_u(x ( ) Ly Q)]f(x)dx] g(y)dy c_bQ c_mL G( )

(4)

Di erentiating E_c with respect to Q; L and , we have

$\frac{@E_c}{@Q}$ = (s v + c_u) pF ($\frac{Q}{()}$) + $\int_0^1$ F ($\frac{Ly+Q}{()}$) g(y)dy + s + c_u c_b (5)

$\frac{@E_c}{@L}$ = (s v + c_u) $\int_0^1$ F ($\frac{Ly+Q}{()}$) g(y)dy + (s + c_u) Y c_m (6)

$\frac{@E_c}{@}$ = ^{0}( )(s v + c_u) "p $\int_0^{Q/()}$ xf(x)dx + $\int_0^1$ ($\int_0^{(Ly+Q)/()}$ xf(x)dx) g(y)dy # c_u $_0$( ) G ( ); (7)

$\frac{@^2E_c}{@Q^2}$ = $\frac{(s\ v + c_u)}{()}$ pf ($\frac{Q}{()}$) + $\frac{(s\ v + c_u)}{()}$ $\int_0^1$ f ($\frac{Ly+Q}{()}$) g(y)dy < 0; 8s > v; (8)

$\frac{@^2E_c}{@L^2}$ = ( ) $\int_0^1$ y^2f ($\frac{Ly+Q}{()}$) g(y)dy < 0; 8s > v; (9)

$\frac{@^2E_c}{@^2}$ = $\frac{(s\ v + c_u)}{}$ ($\frac{^0())^2}{()}$ p ($\frac{(s\ v + c_u)Q^2}{}$ f ($\frac{Q}{()}$) ...) Y c_u ^{00}( ) G^0( )

$\frac{(s\ v + c_u)}{}$ $\frac{^0())^2}{()^3}$ $\int_0^1$ $(Ly + Q)^2$f ($\frac{Ly+Q}{()}$) g(y)dy < 0; 8s > v; (10)

$\frac{@^2E_c}{@L@Q} = \frac{@^2E_c}{@Q@L}$ = $\frac{(s\ v + c_u)}{()}$ $\int_0^1$ yf ($\frac{Ly+Q}{()}$) g(y)dy < 0; 8s > v; (11)

$\frac{@^2E_c}{@\ @Q} = \frac{@^2E_c}{@Q@}$ = $\frac{(s\ v + c_u)\ ^0()}{^2()}$ pQf ($\frac{Q}{()}$) + $\int_0^1$ (Ly + Q)F ($\frac{Ly+Q}{()}$) g(y)dy > 0; 8s > v; (12)

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$$\frac{@^2E_C}{@\ @L} \quad \frac{@^2E_C}{=@L@} \quad = \frac{(s\ \ v + c_u)\ ^0(\ )}{^2(\ )} \quad {}_1 \quad Z_0 \quad y(Ly + Q)f \quad \frac{Ly + Q}{(\ )} \quad g(y)dy > 0; \quad 8s > v; \qquad (13)$$

Here in in above we have partially di erentiated the pro t function in Equation (4) to evaluate the optimal (maximum) pro t of the coordinated or centralized environment. We can characterize the optimal planned order quantity Q, the optimal order quantity L and Promotional/advertising e ort through the rst-order conditions by equating the Equation (5), (6) and (7) to 0 and thereafter solved by numerically (using Mathematica 14.0). The following Proposition 3.1 states that the objective function in (4) is concave. Hence, the optimal production quantity, order quantity and promotional e ort from the secondary supplier can be determined easily.

Proposition 3.1 The integrated supply chain expected pro t function $E_C(Q; L;)$ is jointly concave in Q; L and .

Proof To check whether the pro t function ($E_C(Q; L;)$) is concave, we determine its Hessian matrix $H(E_C(Q; L;))$.

$$H(E_C(Q; L;)) = \begin{bmatrix} \frac{@^2E_C}{@Q^2} & \frac{@^2E_C}{@Q@L} & \frac{@^2E_C}{@Q@} \\ \frac{@^2E_C}{@L@Q} & \frac{@^2E_C}{@L^2} & \frac{@^2E_C}{@L@} \\ @^2E_C & @^2E_C & @^2E_C \end{bmatrix} \qquad (14)$$

Here, the leading principle minors of $H(E_C(Q; L;))$ are

$$D_{11} = \frac{(\ )}{(s\ \ \ v + c_u)}\ pf\ \frac{(\ )}{Q}\ \ {}_1 f\ \frac{(\ )}{Ly + Q}\ g(y)dy\ < 0; \ \ 8s > v;$$

$$D_{22} = \frac{@_2E_c}{\frac{@^2E_c}{@Q^2}} \quad \frac{@_2E_{2c}}{\frac{@^2E_c}{@Q@L}}$$

$$\frac{s\ \ v + c}{\ } \quad 2 \quad {}_1 \quad \frac{Ly + Q}{\ } \quad \frac{Q}{\ } \quad {}_1 \quad \frac{Ly + Q}{\ }$$

$$@L@Q \quad @L$$

$$= \frac{u}{(\ )}\ \ Z_0\ y^2f\ (\ )_2\ g(y)dy\ \ pf\ \ (\ )^+\ Z_0\ f\ (\ )\ g(y)dy$$

$$1 \quad yf \quad \frac{(\ )}{Ly + Q} \quad g(y)dy$$

$$= S\ \frac{(\ )}{v + c}\ u\ {}_2\ \ AB\ \ C^2 > 0; \ \ 8s > v;$$

D_{33} = @^2E_c @Q^2 @^2E_c | @^2E_c @Q@L @^2E_c | @^2E_c @Q@ @^2E_c

= @ ^2E_c @Q^2 | 2 @ E_c @ @L^2 @^{2} ^2E_c | @ 2 @ @L E_c @ ^2E_c @L@ | @ ^2E_c @Q@L | @ ^2E_c @L@Q | @ ^2E_c @ ^{2} | @ 2 @L@ E_c @ ^2E_c @ @Q

+ @^2E_c @Q@ | @^2E_c @L@Q | @^2E_c @ @L | @^2E_c @L^2 | @^2E_c @ @Q

() p Q () 1 Ly+Q () ! xf(x)dx # g(y)dy (AB C^2)

0 ^{2} () Q Ly + Q

(s v + cu)^3 ^{5}() pQ^{2}f () Y + Z 0 1 (Ly + Q)^{2}f () g(y)dy (AB C^2)

(s v + cu)^s u () ! (AB C^2)

c 00 + G^{00}()

0^2 () Q 1 Ly + Q

2(s v + cu)^3 ^{5}() pQf(())+ Z 0 (Ly + Q)f () g(y)dy

1 yf () Ly + Q 1 y(Ly + Q)f () g(y)dy Ly + Q

0 2 () 1 Ly + Q 2

+(s v + cu)^3 ^{5}() Z0 y(Ly + Q)f () g(y)dy B 2

2

+(s v + cu)^3 ^{5}() pQf () + Z 0 (Ly + Q)f () g(y)dy A

Where, A = 1 y^{2}f () Ly + Q g(y)dy; B = pf () Q + Z0 1 () Ly + Q g(y)dy

Ly + Q 1 yf g(y)dy 2

AB C^2 = pf Q 1 y^{2}f () Ly + Q g(y)dy + 1 f () Ly + Q g(y)dy

1 () Ly + Q g(y)dy Z0 1 Ly + Q () 2 g(y)dy ;

Here, if we assume that A < 0 and B < 0, then AB C^2 > 0 and D_{33} < 0. Again, if we assume that A > 0 and B > 0, then AB C^2 > 0 and D_{33} > 0. Therefore, in this policy we assume that A < 0 and B<0.

So, the values of the all leading principle minors D_{11}; D_{22} and D_{33} of the Hessian matrix H(E_c(Q; L;)) are alternate sign for optimal values of Q; L and . Therefore, the Hessian matrix H(E_c(Q; L;) is negative de nite, and consequently the function E_c(Q; L;) is concave.

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Proposition 3.2 If

A = Z0 1 ( ) Ly + Q g(y)dy; B = pf ( ) + Q Z0 1 ( ) Ly + Q g(y)dy

and s > v, then optimal value of Q; L; & are uniquely solved by

pF ( ) + Q 1F ( ) Ly + Q g(y)dy = s v u + cu b s + c c (1

Z0 1 ( ) Ly + Q g(y)dy = (s u v + cu) (s + c) Y cm (1

Q () Ly+Q () cu () + G () (1

From the Proposition 3.2, we can obtain the maximum expected pro t of the integrated supply chain. Determine the value of Q; L and (using Mathematica 9.0). If the total pro t function of the chain E_C(Q; L;) attained maximum value for Q; L and , then this values of Q; L and are called optimal solution for this integrated supply chain model.

Here, in Proposition 3.1, we are going to see the objective function (3) is concave or not, and in Proposition 3.2, we shall determine the optimal (maximum) value of Q; L and for the pro t function E_C(Q; L;).

4 Numerical example

When demand follows the function D(x,)=x* ( ) and x follows the normal distribution i.e.,

f(x) = n p 1 2 exp 2 (1 x mx)2 ; for < x < 1

q d c ; if x [c; d]

g(y) = 0; o:w: 2

We consider the values of the key parameters in appropriate units as follows: m_x = 100, $_x$ = 5, c = 0:35,

d = 1, c_u = \$5, s = \$27, v = \$5, c_b = \$12, c_m = \$4, = 5, = 0:25, m = 2, p = 0:25, q = 0:75, k = 7

Then, the optimal solutions are L = 747:890 Q = 513:03, $_c$ = 8:6800 and the maximum pro t is E_C = 9685:95 .

5 Sensitivity Analysis

Now we will study the sensitivity analysis of the key parameters and the features of analysis have been discussed below. Here we have studied the changes of optimal variables and pro t with (30%; 20%; 10%; + 10%; +20%; +30%) changes in the key parameters. The key parameters that are considered here are the retail selling price per unit of retailer (s), unit production of the manufacturer (c_m), shortage cost per unit (c_u), unit salvage value (v)(cf. Table 3) and the unit production cost of the back-up supplier

(c_b)(cf. Table 4). We observed the change in the nature of the optimal solution due to the sensitivity analysis and presented the results of sensitivity analysis for the parameters s (cf. Table 1), c_u (cf. Table 2), v (cf. Table 3), c_b (cf. Table 4) and c_m (cf. Table 5) in the following tables:

Table 1: Sensitivity Analysis of s (Unit selling price of the retailer)

Change of s (%)	Optimal values of variables			
	L	Q		E_c
-30 %	846.882	412.324	6.8850	4902.72
-20 %	804.823	453.169	7.5667	6466.06
-10 %	773.038	458.877	8.1567	8063.30
-0.0%	747.890	513.030	8.6800	9685.95
+10 %	727.334	536.184	9.1548	11328.5
+20 %	710.103	556.296	9.5889	12987.1
+30 %	695.378	574.041	9.9056	14659.1

Table 2: Sensitivity Analysis of c_u (Under stock cost of the retailer)

Change of c_u (%)	Optimal values of variables			
	L	Q		E_c
-30 %	763.967	500.344	8.6937	9728.30
-20 %	758.387	504.712	8.6893	9713.81
-10 %	753.033	508.940	8.6850	9699.69
-0.0%	747.890	513.030	8.6800	9685.95
+10 %	742.950	517.011	8.6768	9672.54
+20 %	738.193	520.867	8.6728	9659.47
+30 %	733.611	524.613	8.6689	9646.72

Table 3: Sensitivity Analysis of v (Unit salvage value/return price of goods unsold by the retailer to manufacturer)

Change of v (%)	Optimal values of variables			
	L	Q		E_c
-30 %	590.022	418.895	9.1740	8937.01
-20 %	577.526	419.208	8.5458	9248.89
-10 %	568.315	519.076	8.6088	9451.20
-0.0%	747.890	513.030	8.6800	9685.95
+10 %	1404.18	485.739	8.7768	10004.6
+20 %	3122.69	337.227	10.033	19825.4
+30 %	3808.55	225.199	13.629	27941.7

Table 4: Sensitivity Analysis of c_b (Production cost of the backup supplier)

Change of c_b (%)	Optimal values of variables			
	L	Q		E_c
-30 %	140.876	795.157	9.3270	11968.3
-20 %	367.573	670.618	9.0905	11095.7
-10 %	556.629	585.308	8.8768	10344.2
-0.0%	747.890	513.030	8.6800	9685.95
+10 %	958.752	445.065	8.5024	9111.23
+20 %	1205.07	375.935	8.3433	8618.24
+30 %	1513.43	299.391	8.2074	8211.88

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Table 5: Sensitivity Analysis of c_m (Production cost of the main supplier)

Change of c_m (%)	Optimal values of variables			
	L	Q		E_c
-30 %	1333.57	825.309	7.3354	8253.09
-20 %	1186.77	973.271	9.9623	14415.0
-10 %	2072.06	427.710	8.7951	10066.2
-0.0%	747.890	513.030	8.6800	9685.95
+10 %	463.104	556.799	8.6226	9495.61
+20 %	308.934	591.343	8.5842	9371.86
+30 %	196.045	623.242	8.5588	9290.49

6 Conclusion

This paper makes several theoretical and practical contributions applied in industries. This paper studies the coordination issue of a supply chain consisting of one retailer and two suppliers, one is main supplier and another is backup supplier. It generalizes the framework for nding the ecnomic order quantity where the main supplier's yield is subject to disruption and the retailer faces a random demand. We determine the retailer's optimal ordering policy and the main supplier's production quantity that maximize expected pro t of the centralized supply chain. Supply disruption and random yield of the manufacturer along with the buy back contract and promotional e ort have been the core area of concentration in this research work. While considering the sales price and advertising/promotional costs shared by the manufacturer and the retailer for uncertain demand of the end customers are considered altogether. It also demonstrates how the coordinating contract of incentives controls the overall performance of the chain. The generalized model is tested by usual distribution function applied in industries. These results are very useful for the manufacturer and the retailer to decide how to coordinate the supply chain.

For further research interest ,it is worth considering some other situations such as multiobjective supply chain in the system or taking the demand to be deterministic type or introducing some possibilities of deteriorating items etc. To add to the list, the proposed model can even be further extended in several ways. For example, we may generalize the model to allow idle times, nite replenishment rates, variable production rates etc.

References

[1] H. Gurnani, R. Akella, and J. Lehoczky, Optimal order policies in assembly systemswith randomde-mand and randomsupplier delivery, IIE Transactions, 28, (11), 865-878, 1996.

[2] K.Moinzadeh andH. L. Lee, Approximate order quantities and reorder points for inventory systems where orders arrive in two shipments, Operations Research, 37,(2), 277-287, 1989.

[3] S. K. Mukhopadhyay and H. Ma, Joint procurement and production decisions in remanufacturing under quality and demand uncertainty, International Journal of Production Economics, 120, (1), 5-17, 2009.

[4] Y. Gerchak and A. Grosfeld-Nir, Multiple lot-sizing, and value of probabilistic information, in pro-duction to order of an uncertain size, International Journal of Production Economics, 56-57, 191-197, 1998.

[5] Y.He and X. Zhao, Coordination inmulti-echelon supply chain under supply and demand uncertainty, International Journal of Production Economics, 139,(1), 106115, 2012.

[6] Ivanov, D., Dolgui, A., Sokolov, B., Ivanova, M.,. Disruptions in supply chains and recovery policies: state-of-the art review. IFAC-PapersOnLine 49, 1436-1441,2016. https://doi.org/10.1016/j.ifacol.2016.07.773

[7] M. G.Guler and T. Bilgic, On coordinating an assembly system under random yield and random demand, European Journal of Operational Research, 196, (1), 342-350, 2009.

[8] B. Keren, The single-period inventory problem: extension to randomyield fromthe perspective of the supply chain, Omega, 37, (4), 801-810, 2009.

[9] X. Li, Y. Li, and X. Cai, A note on the random yield from the perspective of the supply chain, Omega, 40, (5), 601-610, 2012.

[10] Kotler, P.," A Framework for Marketing Management".,PrenticeHall,NewJersey,2001.

[11] Blattberg, R.C.,Neslin,S.A.," Salespromotion: the long and the short of it".Marketing Letters 1(1), 81-89,1989.

[12] Krishnan, H.,Kapuscinski,R.K.,Butz,D.A.,"Coordinating contracts for decentralized supply chain with retailer promotional e ect". Management Science 50(1),48-62, 2004.

[13] Abad, P.L., "Optimal price and lot size when the supplier o ers a temporary price reduction over an interval".Computers and Operations Research 30(1),63-74,2003.

[14] Kurata,H.,Liu,J.J.,"Optimal promotion planningdepth and frequencyfor atwo-stage supply chain under Markovswitching demand". European Journalof OperationalResearch, 177(2), 1026-1043,2007.

[15]

[15] Szmerekovsky,J.G.,Zhang,J.,"Pricing and two-tier advertising with one manufacturer and one re-tailer.European Journal of Operational Research,192,904-917,2009.

[16] Xie, J.,Wei,J.C.,"Coordinating advertising and pricingin a manufacturerretailerchannel".European Journal of Operational Research,197,785-791,2009.

[17] Xie, J.,Neyret,A., "Co-op advertisin gand pricing models in manufacturerretailer supply chains".Computers and Industrial Engineering, 56(4),1375-1385, 2009.

[18] K. B. Hendricks and V. R. Singhal, The e ect of supply chain glitches on shareholder wealth, Journal of Operation, Management, 21,(5), 501-523, 2003.

[19] S. Pochard, Managing risks of supply-chain disruptions: dual sourcing as a real option [M.S. thesis], Technology and Policy, The Massachusetts Institute of Technology, 2003.

[20] A. Sarkar and P. K. J. Mohapatra, Determining the optimal size of supply base with the consideration of risks of supply disruptions, International Journal of Production Economics, 119, (10, 122-135, 2009.

[21] J. Spengler, Vertical integration and antitrust policy, Journal of Political Economy,58, (4), 347-352, 1950.

[22] A. Roy et al." E ect of cooperative advertising policy for two layer supply chain". International Journal of Management Science and Engineering Management, Taylor and Francis,, 10, 89-101,2014.

[23] H. Emmons and S. N. Gilbert, The role of returns policies in pricing and inventory decisions for catalogue goods, Science, 44, (2), 276283, 1998.

[24] S.Webster and S. K.Weng, A risk-free perishable item returns policy, Manufacturing and Service Operations Management, 2, (1), 100-106, 2000.

[25] Y. Gerchak and Y. Wang, Revenue-sharing vs. wholesaleprice contracts in assembly systems with random demand, Production and OperationsManagement, 13,(1), 23-33, 2004.

[26] G. P. Cachon and M. A. Lariviere, Supply chain coordination with revenue-sharing contracts: strength and limitation, Management Science, 51,(1), 30-44, 2005.

[27] M. A. Lariviere and E. L. Porteus, Selling to the newsvendor: an analysis of price-only contracts, Manufacture and Service Operations Management, 3, (4), 293305, 2001.

[28] C. L. Li and P. Kouvelis, Flexible and risk-sharing supply contracts under price uncer-tainty,Management Science, 45, 10, 1378-1398, 1999.

[29] C. Corbett and X. Groote, A suppliers optimal quantity discount policy under asymmetric informa-tion, Manage-Ment Science, vol. 46, no. 3, pp. 444450, 2000.

[30] A. A. Tsay, The quantity exibility contract and suppliercustomer incentives, Management Science, 45, (10), 1339-1358, 1999.

[31] T. A. Taylor, Coordination under channel rebates with sales e ort e ect, Management Science, 48,(8), 992-1007, 2002.