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Mathematical Model Of Foreign Exchange Risk In A Supply Chain With Newsvendor Setting Using A Log-Normally Distributed Exchange Rate Error And Isoelastic Demand

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Abstract: *In a global supply chain consisting of one retailer and one manufacturer, both from different countries, when there is a time lag between the payments made while placing the order and the time when the order is realized, risk in the form of exchange rate fluctuation affects the optimal pricing and order quantity decisions. We elaborate the effect of exchange rate fluctuation under Log-normal distribution when the retailer or manufacturer undertakes to share the exchange rate risk and the demand error is modelled in the multiplicative form in the news vendor framework.We have observed our model by changing the values of parameter also.*
Keywords: *Transaction Exposure, Exchange Rate Error, Newsvendor Problem, Optimal Pricing and Quantity, Log-normal distribution.*

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I. Introduction

Foreign exchange exposure refers to the risk associated with the foreign exchange rates that change frequently and can have an adverse effect on the financial transactions denominated in some foreign currency rather than the domestic currency of the company. In short, the firm's risk that its future cash flows gets affected by the change in the value of the foreign currency.

A risk faced by the company that while dealing in the international trade, the currency rates may change before making the final settlement, is termed as a Transaction exposure. The greater the time gap between the agreement and the final settlement, the higher is the risk associated with the change in the foreign exchange rates.Arcelus, Gor and Srinivasan have invented a mathematical model in news vendor framework to find most favorable ordering and pricing strategies for exporter and producer, when the two countries doing the business, faces transaction exposure. The complete derivation of optimum strategies and expected profit of the exchange rate risk model for multiplicative demand is given in Sanjay Patel, Ravi Gor. Our main contribution in this paper is to explain the effect of Log-normal distribution in the exchange rate error under the isoelastic demand with multiplicative error in news vendor setting.

II. Literature Review

This paper follows Arcelus, Gor and Srinivasan's [1] mathematical model. Transaction exposures by firms with receivables or payables in foreign currencies have been reported in Goel [9]. It is the nature of global trade that a buyer or a seller must bear what is known in the international finance field as transaction exposure, Eitemann et al., [7], Shubita et al., [8].

By Petruzzi and Dada [6], a newsvendor framework was invented and the price dependent demand forms in the additive and multiplicative error by Mills [4], Karlin and Carr [5] have been used. In Patel and Gor [10], the maximum profit and ideal strategy are derived for linear demand forms and for multiplicative demand forms.A new hybrid model was developed for additive and multiplicative demand errors [11]. In a Newsvendor framework, Mehta and Gor [15] modeled exchange rate errors using Gamma distributions. The effect of a log-normal distribution on the exchange rate error under linear demand in news vendor settings is modeled by Mehta and Gor [16].The authors have also developed a model for the exchange rate error under a Gumbel distribution [17] and under Exponential distribution [18].

III. Transaction Exposure Model

Suppose exporter wants to order q units from a foreign producer of some product. The exporter does not know the demand(D) of the product, which is undecided. But the demand depends on the price(p) and also it is random. In this paper, we consider the price dependent demand with multiplicative error which can be given as,

$D(p,\epsilon) = g(p)\epsilon$, where ϵ is the multiplicative error in the demand and it follows some distribution with mean μ in interval [A,B] and $g(p) = ap^{-b}, a, b > 0$ is the multiplicative demand error.

Let us denote exchange rate as 'r' in the exporter currency when the order is placed. Let w denotes the cost of one unit of the product in the producer currency. If buyer pays on the settlement day then he has to pay wr per unit of the product in his currency. Suppose, there is some time between order is placed and the amount is paid for the product, there exists transaction exposure risk, since the exchange rate may differ. So, the buyer has to pay more or less, depending on the existing rate on the day arrival of the product. We model future exchange rate as,

FER= Current exchange rate+ fluctuation in the exchange rate.

The difference in the exchange rate is some percentage of r, so we take FER= $r + r\epsilon_r = r(1+\epsilon_r)$, where ϵ_r is a random variable together with the variable D. We considerϵ_r lies in $[-a, a]$. Here $0 < a < 1$. The value of ϵ_r is unknown but it depends on distribution $\psi(\epsilon_r)$. In this paper we assume gamma distribution for ϵ_r with support $[a, b]$i.e.$\psi(y) = k\theta$. The expected value of the fluctuation in exchange rate is, $E(y) = \frac{a+b}{2}$. If the exchange rate fluctuationϵ_r is positive, buyer has to pay more and if it is negative then seller will get less. So, who will bare the exchange rate risk? In this paper, we will discuss two scenarios under multiplicative demand error. In both the cases, the exporter's optimal policy is to determine the optimum order(q) and selling price(p) of the product. So, his expected profit is maximum. Also, we will obtain the strategies for producer as well.

IV. Assumptions And Notations

We will consider the following assumptions in the foreign exchange transaction exposure model:

I. The standard newsvendor problem assumptions apply.

II. The global supply chain consists of single retailer-single manufacturer.

III. The error in demand is multiplicative.

IV. Only one of the two-retailer or manufacturer- bears the exchange rate risk.

The following notations are used in the paper:

q= order quantity

p= selling price per unit

D= demand of the product= no. of units required

ϵ= demand error= randomness in the demand.

V= salvage value per unit

s=penalty cost per unit for shortage

c= cost of manufacturing per unit for manufacturer

wr = purchase cost for retailer

ϵ_r= the exchange rate fluctuation= exchange rate error= randomness in exchange rate

Π= profit function.

The two scenarios:

Case 1: Exporter bears the exchange rate risk

Suppose, we consider that exporter bears the exchange rate risk and producer does not bear. Hence, the producer will get w per unit at any time and the buyer has to pay according to the existing exchange rate. So, buyer will pay $wr(1+\epsilon_r)$ per unit, on the settlement day. This amount in producer's currency is$\frac{wr(1+\epsilon_r)}{r} = w(1+\epsilon_r) = W_r$. Hence, W_r is the purchase cost to buyer in seller's currency. Now, the exporter will choose the selling price p & order quantity q, to maximize his expected profit. The profit function of the exporter is given by,

$\Pi(p,q)$=[revenue from q items]– [expenses for the q items]

$$\Pi(p,q) = \begin{cases} [pD + v(q-D)] - [qw_r] if D \le q \; (overstocking) \\ [pq] - [s(D-q) + qw_r] if D > q \quad (shortage) \end{cases}$$

All the parameters p, v, s, w_r are taken in producer's currency and the selvage value v is taken as an income from the disposal of each of the $q - D$ leftovers.

Since, the demand $D(p,\epsilon) = g(p)\epsilon$ the exporter's profit function is given by,

$$\Pi(p,q) = \begin{cases} p(g(p) \in) + v(q - g(p) \in) - qw_r if D \le q \\ pq - s(g(p) \in -q) - qw_r if D > q \end{cases}$$

Putting $g(p) = g$ and define $z = q/g(p) = q/gi.e.q = gz$, for the multiplicative demand error. Now, $D \le q \Leftrightarrow g \in \le q \Leftrightarrow \in \le q/g \Leftrightarrow \in \le z$and similarly $D > q \Leftrightarrow \in > z$

$$\Pi(z,p) = \begin{cases} pg \in +vg(z-\in) - w_r zg, \ if \in \le z \\ pgz - sg(\in -z) - w_r zg, if \in > z \end{cases} \quad (2)$$

The equation (2) describes the profit function for the retailer in the manufacturer currency. Note that the parameter q is replaced by *z*. Now the retailer wants to find the optimal order quantity q say q^* and optimal price $p = p^*$ to maximize his expected profit. In order to do this he must find optimal values of the price p and the parameter *z*, say p^* and z^* respectively which maximizes his expected profit so that he can determine the optimal order $q^*=z^*g(p^*)$. The profit Π is a function of the random variable ∈ with support [A, B]. Thus the retailer's expected profit is given by,

$$E\Pi(z,p) = \int_A^B \Pi(z,p) f(u) du.$$

$$E\Pi(z,p) = \int_A^z [pgu + vg(z-u) - gzw_r] f(u) du + \int_z^B [pgz - sg(u-z) - gzw_r] f(u) du.$$

Define $\Lambda(z) = \int_A^z (z-u) f(u) du$[expected leftovers] and

$\Phi(z) = \int_z^B (u-z) f(u) du$ [expected shortages]

Then the expected profit of the retailer as a function of *z* and *p* is given by,

$E\Pi(z,p) = (p - w_r)(g\mu) - g(w_r - v)\Lambda - (p + s - w_r)\Phi$ (4) as derived in Sanjay Patel and Ravi Gor. Where $\mu = \int_A^B uf(u)du$ in the equation (4) and it gives the expected value of the randomness u in the demand D.

We use whitin's method to maximize the expected profit function. In this method first we keep p fixed in (4) and use the second order optimality conditions $\frac{\partial E}{\partial z} = 0 \ and \frac{\partial^2 E}{\partial z^2} < 0$ to find the optimum value of z^* as a function of function p. Then we substitute the value of z^* in the expected profit (4) so that it becomes a function of single variable p and hence the optimal p^* can also be obtained. The authors have already derived the optimal policies given below, in Sanjay Patel and Ravi Gor.

$z^* = F^{-1}\left(\frac{p+s-w_r}{p+s-v}\right)$ (5) where $F(z) = \int_A^z f(u) du$is the CDF.

The retailer's optimal order quantity $q = q^*$ is given by

$q^* = g(p^*)z^* = g(p^*)F^{-1}\left(\frac{p^*+s-w_r}{p^*+s-v}\right)$ (6)

Also the manufacturer's profit when the buyer bears the risk is [(selling price of seller)-(cost of purchase to seller)]× no. of units sold, $\Pi_m = (w - c)q^*$ (7)

Case:2 Seller bears the exchange rate risk

We assume that the manufacturer bears theexchange rate risk and retailer does not. Thus the retailerpays *w* per unit in manufacturer's currency at any point oftime and the manufacturer will get according to the existingexchange rate. So the manufacturer will be getting $\frac{wr}{r(1+\epsilon_r)} = w_m$per unit on the settlement day in his currency. Now the retailer's profit function, his expected profit and optimal policies to get maximum expected profit can be obtained by replacing *wr*by *w* in case-1. So we get the retailer's profit as,

$$\Pi(p,q) = \begin{cases} [pD + v(q-D)] - [qw], if D \le q \ (overstocking) \\ [pq] - [s(D-q) + qw], if D > q \qquad (shortage) \end{cases} \quad (8)$$

And his expected profit as,

$E\Pi(z,p) = (p - w)(g\mu) - g[(w - v)\Lambda + (p + s - w)\Phi]$ (9)

The optimal value of z is given by $z^* = F^{-1}\left(\frac{p+s-w}{p+s-v}\right)$ and hence the optimum order quantity is, $q^* = g(p^*)z^* = g(p^*)F^{-1}\left(\frac{p^*+s-w}{p^*+s-v}\right)$ (10). Also the manufacturer's profit when the buyer bears the risk is [(selling price of seller)-(cost of purchase to seller)]× no. of units sold, $\Pi_m = (w_m - c)q^*$ (11)

V. SENSITIVITY ANALYSIS

Here, we have consider isoelastice demand with multiplicative demand error u which follows the uniform distribution $f(u)$ with support [A,B]. We get the ideal strategy and maximum expected profit of the exporter and producer using MAPLE software when either exporter or producer takes the exchange rate risk. We figure out the ideal optimum values by using Log-normal distribution $\psi(\epsilon_r)$ in the exchange rate error ϵ_r with support [0.1,0.2]. The probability density function of Log-normal distribution is,

$$f(x) = \frac{1}{x\sigma\sqrt{2\pi}} \exp\left(-\frac{(lnx - \mu)^2}{2\sigma^2}\right)$$

With mean$E[X] = e^{\mu + \frac{1}{2}\sigma^2}$. Here, X is a log-normally distributed random variable and two parameters μ&σ are

mean and standard deviation of the variable's natural logarithm respectively.
We will consider following parameter values:
Demand support= [A,B]=[0.7,1.1]
Mean demand= $\mu = \frac{A+B}{2} = 0.9$
Isoelastic demand $g(p) = ap^{-b}, a = 500{,}000{,}000, b = 2.5$
Salvage value $v = 10$
Penalty cost $s = 5$
Cost of producing per unit for producer $c = 20$
Current exchange rate $r = 45$
The following results in case-I and case-II we get using MAPLE software.

5.1 MAPLE code for Log-normal distribution whe buyer bears the risk
The expected value of the exchange rate error er=erx in [el,eu] using probability density function of Log-normal distribution is:

$$erx := eval\left(\int_0^{\infty} (el + (eu - el)\cdot x)\cdot\left(\frac{e^{-\frac{1}{2}\cdot\left(\frac{\ln(x)-\mu}{\sigma}\right)^2}}{\sqrt{2\pi}\cdot\sigma\cdot x}\right)dx, \{\mu = 0.0001, \sigma = 0.33\}\right)$$

$$erx := 0.2056065279$$

$$wr := w\cdot(1 + erx)$$

$$wr := 1.205606528\,w$$

$$E\Pi := (p - wr)\cdot g(p)\cdot\mu - g(p)\cdot(wr - v)\cdot\Lambda - g(p)\cdot(p + s - wr)\cdot\Phi$$

$$E\Pi := (p - 1.205606528\,w)\,a\,p^{-b}\,\mu - a\,p^{-b}\,(1.205606528\,w - v)\left(\int_A^{\frac{q}{a\,p^{-b}}}\left(\frac{q}{a\,p^{-b}} - u\right)f(u)\,du\right) - a\,p^{-b}\,(p + s - 1.205606528\,w)\left(\int_{\frac{q}{a\,p^{-b}}}^{B}\left(-\frac{q}{a\,p^{-b}} + u\right)f(u)\,du\right)$$

$$E\Pi r := eval\left(E\Pi, \left[a = 500000000, b = 2.5, v = 10, s = 4, A = .7, B = 1.1, f(u) = \frac{1}{0.4}, \mu = .9\right]\right)$$

$$E\Pi r := \frac{4.500000000 \times 10^{8}\,(p - w)}{p^{2.5}} - \frac{1}{p^{2.5}}\Big(500000000\,(w - 25)\,\big(5.000000000 \times 10^{-9}\,q\,p^{5/2}\,(2.000000000 \times 10^{-9}\,q\,p^{5/2} - 0.7000000000) - 5.000000000 \times 10^{-18}\,q^2\,p^5 + 0.6125000000\big)\Big) - \frac{1}{p^{2.5}}\Big(500000000\,(p + 5 - w)\,\big(-5.000000000 \times 10^{-9}\,q\,p^{5/2}\,(1.100000000 - 2.000000000 \times 10^{-9}\,q\,p^{5/2}) + 1.512500000 - 5.000000000 \times 10^{-18}\,q^2\,p^5\big)\Big)$$

$$DqE\Pi r := \frac{\partial}{\partial q}E\Pi r$$

$$DqE\Pi r := -2.500000000\,(w - 25)\,\big(2.000000000 \times 10^{-9}\,q\,p^{5/2} - 0.7000000000\big) + 2.500000000\,(p + 5 - w)\,\big(1.100000000 - 2.000000000 \times 10^{-9}\,q\,p^{5/2}\big)$$

$\xrightarrow{\text{solve for q}}$

$$\left[\left[q = \frac{5.0000000 \times 10^{7}\,(11.\,p - 4.\,w - 120.)}{p^{5/2}\,(p - 20.)}\right]\right]$$

$DpE\Pi r := \frac{\partial}{\partial p} E\Pi r$

$$DpE\Pi r := \frac{4.500000000 \times 10^{8}}{p^{2.5}} - \frac{1.125000000 \times 10^{9}\,(p - w)}{p^{3.5}} + \frac{1}{p^{3.5}}\Big(1.250000000 \times 10^{9}\,(w - 25)\,\big(5.000000000 \times 10^{-9}\,q\,p^{5/2}\,\big(2.000000000 \times 10^{-9}\,q\,p^{5/2} - 0.7000000000\big) - 5.000000000 \times 10^{-18}\,q^{2}\,p^{5} + 0.6125000000\big)\Big) - \frac{6.250000000\,(w - 25)\,q\,\big(2.000000000 \times 10^{-9}\,q\,p^{5/2} - 0.7000000000\big)}{p^{1.000000000}} + \frac{1}{p^{3.5}}\Big(1.250000000 \times 10^{9}\,(p + 5 - w)\,\big(-5.000000000 \times 10^{-9}\,q\,p^{5/2}\,\big(1.100000000 - 2.000000000 \times 10^{-9}\,q\,p^{5/2}\big) + 1.512500000 - 5.000000000 \times 10^{-18}\,q^{2}\,p^{5}\big)\Big) - \frac{1}{p^{2.5}}\Big(500000000\,\big(-5.000000000 \times 10^{-9}\,q\,p^{5/2}\,\big(1.100000000 - 2.000000000 \times 10^{-9}\,q\,p^{5/2}\big) + 1.512500000 - 5.000000000 \times 10^{-18}\,q^{2}\,p^{5}\big)\Big) + \frac{6.250000000\,(p + 5 - w)\,q\,\big(1.100000000 - 2.000000000 \times 10^{-9}\,q\,p^{5/2}\big)}{p^{1.000000000}}$$

$\xrightarrow{\text{solve for p}}$

$$\left[\left[p = 100.\,RootOf\left(7\,\_Z^{12}\,q^{2} - \_Z^{10}\,q^{2} - 22000\,\_Z^{7}\,q - 36750000\,\_Z^{2} + 7750000\right)^{2}\right]\right]$$

r's expected selling price wm per unit with respect to future rate r(1+rex) is:

$EPm := (w - c) \cdot q$

$$EPm := (w - c)\,q$$

The manufacturer's expected profit E(Πm) for the order q of the retailer and his purchase cost c is:

$E\Pi m := eval\left(EPm, \left\{c = 20, q = \frac{5.0000000 \times 10^{7}\,(11.\,p - 4.\,w - 120.)}{p^{5/2}\,(p - 20.)}\right\}\right)$

$$E\Pi m := \frac{5.000000000 \times 10^{7}\,(w - 20)\,(11.\,p - 4.\,w - 120.)}{p^{5/2}\,(p - 20.)}$$

To determine maximum expected profit of the manufacturer :

$Optimization[interactive]\left(E\Pi m, \left\{q = \frac{5.0000000 \times 10^{7}\,(11.\,p - 4.\,w - 120.)}{p^{5/2}\,(p - 20.)}, DpE\Pi r = 0\right\}\right)$

$$[274028.795995829394, [p = 51.3995726634919, q = 27349.8712872567, w = 30.0193815582419]]$$

Now the retailer determines his expected profit for the above optimal selling prize w of the manufacturer :

$EPr := eval(E\Pi r, w = 30.0193815582419)$

$$EPr := \frac{4.500000000\times 10^{8}\,(p-30.0193815582419)}{p^{2.5}} - \frac{1}{p^{2.5}}\Big(2.509690780\times 10^{9}\,\big(5.000000000\times 10^{-9}\,q\,p^{5/2}\,(2.000000000\times 10^{-9}\,q\,p^{5/2}-0.7000000000) - 5.000000000\times 10^{-18}\,q^{2}p^{5}+0.6125000000\big)\Big) - \frac{1}{p^{2.5}}\Big(500000000\,(p-25.01938156)\,\big(-5.000000000\times 10^{-9}\,q\,p^{5/2}\,(1.100000000-2.000000000\times 10^{-9}\,q\,p^{5/2}) + 1.512500000 - 5.000000000\times 10^{-18}\,q^{2}p^{5}\big)\Big)$$

The maximum expected profit of the retailer for the optimal value w of the manufacturer is :

$Optimization[interactive](EPr)$

$$[485690.975461240858, [p = 51.3995726896702, q = 27349.8712331700]]$$

5.2 MAPLE code for Log-normal distribution when seller bears the risk

$$> erx := eval\left(\int_0^{\infty} (el+(eu-el)\cdot x)\cdot\left(\frac{e^{-\frac{1}{2}\cdot\left(\frac{\ln(x)-\mu}{\sigma}\right)^2}}{\sqrt{2\pi}\cdot\sigma\cdot x}\right)dx, \{\mu = 0.0001, \sigma = 0.33\}\right)$$

$$erx := 0.2056065279$$

$wr := w$

$$wr := w$$

$E\Pi := (p-wr)\cdot g(p)\cdot\mu - g(p)\cdot(wr-v)\cdot\Lambda - g(p)\cdot(p+s-wr)\cdot\Phi$

$$E\Pi := (p-w)\,a\,p^{-b}\mu - a\,p^{-b}\,(w-v)\left(\int_A^{\frac{q}{a\,p^{-b}}}\left(\frac{q}{a\,p^{-b}}-u\right)f(u)\,du\right) - a\,p^{-b}\,(p+s-w)\left(\int_{\frac{q}{a\,p^{-b}}}^{B}\left(-\frac{q}{a\,p^{-b}}+u\right)f(u)\,du\right)$$

$E\Pi r := eval\left(E\Pi, \left[a = 500000000, b = 2.5, v = 25, s = 5, A = .7, B = 1.1, f(u) = \frac{1}{0.4}, \mu = .9\right]\right)$

$$E\Pi r := \frac{4.500000000\times 10^{8}\,(p-w)}{p^{2.5}} - \frac{1}{p^{2.5}}\Big(500000000\,(w-25)\,\big(5.000000000\times 10^{-9}\,q\,p^{5/2}\,(2.000000000\times 10^{-9}\,q\,p^{5/2}-0.7000000000) - 5.000000000\times 10^{-18}\,q^{2}p^{5}+0.6125000000\big)\Big) - \frac{1}{p^{2.5}}\Big(500000000\,(p+5-w)\,\big(-5.000000000\times 10^{-9}\,q\,p^{5/2}\,(1.100000000-2.000000000\times 10^{-9}\,q\,p^{5/2}) + 1.512500000 - 5.000000000\times 10^{-18}\,q^{2}p^{5}\big)\Big)$$

$DqE\Pi r := \frac{\partial}{\partial q}E\Pi r$

$$DqE\Pi r := -2.500000000\,(w-25)\,(2.000000000\times 10^{-9}\,q\,p^{5/2}-0.7000000000) + 2.500000000\,(p+5-w)\,(1.100000000-2.000000000\times 10^{-9}\,q\,p^{5/2})$$

$\xrightarrow{\text{solve for q}}$

$$\left[\left[q = \frac{5.0000000 \times 10^{7}\,(11.p - 4.w - 120.)}{p^{5/2}\,(p - 20.)}\right]\right]$$

$$Dp E\Pi r := \frac{\partial}{\partial p} E\Pi r$$

$$Dp E\Pi r := \frac{4.500000000 \times 10^{8}}{p^{2.5}} - \frac{1.125000000 \times 10^{9}\,(p - w)}{p^{3.5}} + \frac{1}{p^{3.5}}\Big(1.250000000 \times 10^{9}\,(w - 25)\,\big(5.000000000 \times 10^{-9}\,q\,p^{5/2}\,\big(2.000000000 \times 10^{-9}\,q\,p^{5/2} - 0.7000000000\big) - 5.000000000 \times 10^{-18}\,q^{2}\,p^{5} + 0.6125000000\big)\Big) - \frac{6.250000000\,(w - 25)\,q\,\big(2.000000000 \times 10^{-9}\,q\,p^{5/2} - 0.7000000000\big)}{p^{1.000000000}} + \frac{1}{p^{3.5}}\Big(1.250000000 \times 10^{9}\,(p + 5 - w)\,\big(-5.000000000 \times 10^{-9}\,q\,p^{5/2}\,\big(1.100000000 - 2.000000000 \times 10^{-9}\,q\,p^{5/2}\big) + 1.512500000 - 5.000000000 \times 10^{-18}\,q^{2}\,p^{5}\big)\Big) - \frac{1}{p^{2.5}}\Big(500000000\,\big(-5.000000000 \times 10^{-9}\,q\,p^{5/2}\,\big(1.100000000 - 2.000000000 \times 10^{-9}\,q\,p^{5/2}\big) + 1.512500000 - 5.000000000 \times 10^{-18}\,q^{2}\,p^{5}\big)\Big) + \frac{6.250000000\,(p + 5 - w)\,q\,\big(1.100000000 - 2.000000000 \times 10^{-9}\,q\,p^{5/2}\big)}{p^{1.000000000}}$$

$$\xrightarrow{\text{solve for p}}$$

$$\left[\left[p = 100.\,RootOf\big(7\,\_Z^{12}\,q^{2} - \_Z^{10}\,q^{2} - 22000\,\_Z^{7}\,q - 36750000\,\_Z^{2} + 7750000\big)^{2}\right]\right]$$

$$wm := \frac{w}{1 + erx}$$

$$wm := 0.8294580170\,w$$

$$EPm := (wm - c)\cdot q$$

$$EPm := (0.8294580170\,w - c)\,q$$

$$E\Pi m := eval\left(EPm, \left\{c = 20, q = \frac{5.0000000 \times 10^{7}\,(11.p - 4.w - 120.)}{p^{5/2}\,(p - 20.)}\right\}\right)$$

$$E\Pi m := \frac{5.000000000 \times 10^{7}\,(0.8294580170\,w - 20)\,(11.p - 4.w - 120.)}{p^{5/2}\,(p - 20.)}$$

$$Optimization[interactive]\left(E\Pi m, \left\{p \geq w, Dp E\Pi r = 0, q = \frac{5.0000000 \times 10^{7}\,(11.p - 4.w - 120.)}{p^{5/2}\,(p - 20.)}\right\}\right)$$

$$[160602.892390223715, [p = 65.6805181765104, q = 14126.2444721385, w = 37.8188093495929]]$$

$$EPr := eval(E\Pi r, w = 37.8188093495929)$$

$$EPr := \frac{4.500000000\times 10^{8}\,(p-37.8188093495929)}{p^{2.5}} - \frac{1}{p^{2.5}}\Big(6.409404675 \times 10^{9}\,\big(5.000000000\times 10^{-9}\,q\,p^{5/2}\,(2.000000000\times 10^{-9}\,q\,p^{5/2}-0.7000000000) - 5.000000000\times 10^{-18}\,q^{2}p^{5}+0.6125000000\big)\Big) - \frac{1}{p^{2.5}}\Big(500000000\,(p - 32.81880935)\,\big(-5.000000000\times 10^{-9}\,q\,p^{5/2}\,(1.100000000-2.000000000 \times 10^{-9}\,q\,p^{5/2}) + 1.512500000 - 5.000000000\times 10^{-18}\,q^{2}p^{5}\big)\Big)$$

$Optimization[interactive](EPr)$

$$[332238.926905238593, [p = 65.6805837059640, q = 14126.2065238763]]$$

Table-1 gives the different observations when salvage values are changed either buyer or seller bears the risk. Table-2 gives the different observations when penalty cost changed either buyer or seller bears the risk.

Table-1
Salvage value changed table

Distribution	Parameters of the distribution	P^*	q^*	Seller's selling price w^*	Optimum expected profit of buyer	Optimum expected profit of seller
			Buyer bears the risk			
Log-normal	*V=10,s=5*	102.90	4187.27	48.56	163013.41	119888.81
	V=15,s=5	102.90	4196.92	48.56	163013.41	119888.81
	V=20,s=5	67.78	12662.16	32.13	313504.58	153671.11
	V=25,s=5	51.39	27349.87	30.01	485690.97	274028.79
			Seller bears the risk			
Log-normal	*V=10,s=5*	70.16	11119.16	39.80	292029.19	144771.91
	V=15,s=5	70.16	11119.17	39.80	292029.19	144771.91
	V=20,s=5	66.90	13099.71	38.25	319860.31	153618.35
	V=25,s=5	65.68	14126.20	37.81	332238.92	160602.89

Table-2
Penalty cost changed table:

Distribution	Parameters of the distribution	P^*	q^*	Seller's selling price w^*	Optimum expected profit of buyer	Optimum expected profit of seller
			Buyer bears the risk			
Log-normal	*V=10,s=4*	51.39	27349.87	30.01	485690.97	274028.79
	V=10,s=5	102.90	4187.27	48.56	163013.41	119888.81
	V=10,s=6	58.14	18059.25	32.87	389905.96	232461.36
	V=10,s=8	58.37	18011.41	32.85	388853.14	231577.06
			Seller bears the risk			
Log-normal	*V=10,s=4*	65.68	14126.20	37.81	332238.92	160602.89
	V=10,s=5	70.16	11119.16	39.80	292029.19	144771.91
	V=10,s=6	70.32	11094.61	39.80	291525.63	144457.67
	V=10,s=8	70.61	11052.18	39.80	290616.97	143881.86

VI. conclusion

We elaborate log-normally distributed exchange rate fluctuation when the retailer or manufacturer undertakes to share the exchange rate risk and the demand error is modeled in the multiplicative form in the news vendor framework. We have also observed our model by changing the values of parameter.

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