Chapter 6

Foreign exchange transaction exposure under multiplicative demand error
6.1 Introduction

We have completely elaborated exchange risk model under additive demand error and all the optimal policies of the retailer and manufacturer in the chapter-5. We have seen that in a global supply chain when two firms from two different countries are into a business how they will face the unexpected changes in the exchange rate fluctuation in the market and the firms also have the problem of taking the decision that who is going to bear the exchange rate fluctuation risk.

In this chapter we discuss the problem of the exchange rate risk in the new vendor format, under isoelastic demand with multiplicative error. We discuss both the cases when either the buyer or the seller undertakes the risk and develop exchange rate risk model under isoelastic demand with multiplicative error. We derive the analytical expression for the expected profit and closed form solutions for optimal policies of the retailer and manufacturer both, for each of the case that who takes the risk.

6.2 Assumptions and Notations

(a) Assumptions:
We impose the following assumptions in the foreign exchange transaction exposure model:

(1) All the standard assumptions of the basic news vendor model are applied.

(2) The global supply chain consists of single retailer- single manufacturer.

(3) The manufacturer and retailer are from different countries having different currency.

(4) The time period between time the financial obligation has been incurred and the time its due to be settled is fixed.

(5) The exchange rate fluctuates during the time period and the due is paid only after the time duration.

(6) The error in demand is multiplicative.

(7) Only one of the two-retailer or manufacturer- bears the exchange rate risk.
(b) Notations:

- \( c \) the cost of purchasing one unit of the product
- \( p \) the selling price per unit of the product
- \( q \) the order quantity of the product
- \( D \) the demand of the product
- \( v \) the salvage value per unit
- \( s \) the penalty cost per unit
- \( \varepsilon \) demand error
- \( \varepsilon_r \) exchange rate error
- \( \Pi(p, q) \) retailer’s profit as function of price \( p \) and order quantity \( q \)
- \( \Pi_m \) manufacturer’s profit
- \( E[\Pi(p, q)] \) expected profit function
- \( \Lambda \) expected leftovers
- \( \Phi \) expected shortages
- \( f(D) \) probability density function (PDF) for continuous demand \( D \)
- \( F(D) \) cumulative distribution function (CDF) for continuous demand
- \( \mu \) mean of probability distribution
- \( \sigma \) standard deviation of probability distribution

### 6.3 Model Formulation

Let there be two firms (or individuals) from two different countries are into a business. Suppose a retailer/buyer (say in India) wants to order \( q \) units from a foreign manufacturer/seller (say in U.S) of a certain perishable product. The retailer does not know the demand \( (D) \) of the product, which is partially price dependent and partially uncertain or random. But but he has information about the demand distribution. We model the demand \( D \) as \( D(p, \varepsilon) = g(p) \cdot \varepsilon \). Where \( g(p) \) is the price dependent deterministic demand and \( \varepsilon \) is the randomness in the demand. Here \( g(p) \) is a decreasing function of the price and the demand error \( \varepsilon \) is a random variable which follows some distribution say, \( f(\varepsilon) \) with mean \( \mu \) and standard deviation \( \sigma \) in some interval \([A,B]\).

In this model we consider isoelastic price dependent demand function \( g(p) = ap^{-b} \), where \( a > 0, b > 1 \) and \( A > 0 \). These restrictions on \( a \& b \) are for keeping the demand positive.
So we have, \( D(p, \varepsilon) = ap^{-b} \cdot \varepsilon \). Therefore this model is referred as the **IDME MODEL** i.e. the Isoelastic Demand with Multiplicative Error model.

Since the demand \( D \) is unknown and random it can be less than or equal to \( q \) or greater than \( q \). If \( D \leq q \) i.e. if the retailer has overstocking of items then he will sell the each of the leftover from \( q - D \) units at the salvage value \( v \) per unit. So \( v \) is the income to the retailer for disposing off the leftovers. On the other hand if \( D > q \) i.e. if there is a shortage of the items or understocking then he will have a loss of profit and it is called the penalty cost. The penalty cost is denoted by \( s \) and it is defined as the loss of income per each item short, if he would have purchased it for the shortages \( D - q \).

As we assume that the two firms or individuals are from two different parts of the globe, their business is definitely influenced by the foreign exchange transaction exposure in the form of exchange rate fluctuations. Let the exchange rate be \( r \) in the retailer’s currency when he places the order. (say e.g. \( 1 \text{\$} = r \text{\ Rs.} \)) Let \( w \) be the cost of one unit of the product in the manufacturer’s currency. If the retailer pays immediately then he has to pay \( wr \) per unit of the product in his currency. But we assume that the time period between, when the financial obligation has been incurred and its due to be settled is fixed and positive. In other words the retailer pays the due only after a fixed time lag. Thus there exists transaction exposure risk, as the exchange rate \( r \) may get fluctuate or change during this period. This risk is known as **exchange rate risk**. So the buyer has to pay more or less according to the existing rate at the time of the arrival of the product.

Generally the fluctuation in the exchange rate \( r \) is very small and uncertain. Also the fluctuation in \( r \) is always some percentage of \( r \), hence we define the **Future Exchange Rate** (F.E.R) as, \( \text{F.E.R} = r + r \cdot \varepsilon_r = r(1+ \varepsilon_r) \). [ e.g. \( 1 \text{\$} = r(1+ \varepsilon_r) \text{\ Rs.} \)] The F.E.R is the actual exchange rate at which the buyer is going to pay the due or seller is receiving. Note that the fluctuation \( \varepsilon_r \) is also a random variable together with the random demand. The fluctuation \( \varepsilon_r \) is unknown but its distribution is known say, \( \psi(\varepsilon_r) \). If the fluctuation \( \varepsilon_r \) is positive buyer has to pay more and if it is negative seller will get less.

So the main question arises is that,

“Who will bear the exchange rate risk?”
The retailer OR The manufacturer?

So we consider two models as follows in the news vendor settings.

1. The retailer bears the exchange rate risk.
2. The manufacturer bears the exchange rate risk.

We develop models for both the scenarios for isoelastic demand with multiplicative error in the next two sections. In each case, the retailer’s objective is to jointly determine the optimum order \(q\) and selling price \(p\) of the product so that his expected profit is maximum. At the same time we obtain the manufacturer’s optimal policies as well.

### 6.3.1 The multiplicative model for the risk taker retailer

In this model we assume that the retailer bears the exchange rate risk and manufacturer does not. So the manufacturer will get \(w\) per unit at any point of time and the retailer will have to pay according to the existing exchange rate that is according to F.E.R. So the retailer will be paying \(wr(1 + \varepsilon_r)\) per unit in his currency, on the settlement day or when he acquires the product. This amount in terms of the manufacturer currency is \(wr(1 + \varepsilon_r)/r = w(1 + \varepsilon_r) = w_r\) (say). Thus \(w_r\) is the purchase cost per unit to the retailer in the manufacturer’s currency. Now the retailer will choose the selling price \(p\) and the order quantity \(q\) so as to maximize his expected profit.

The profit function for the retailer is denoted by \(\Pi(p, q)\) and is given by,

\[
\Pi(p, q) = \begin{cases} 
[pD + v(q - D)] - [qw_r] & \text{if } D \leq q \\
[pq] - [s(D - q) + qw_r] & \text{if } D > q
\end{cases}
\]

(overstocking)

(shortage) (6.1)

Note that all the parameters \(p, v, s, w_r\) are taken in the manufacturer’s currency.

Now put \(D = D(p, \varepsilon) = g(p) \varepsilon\) in the equation (1). So we get,

\[
\Pi(p, q) = \begin{cases} 
[pD + v(q - D)] - [qw_r] & \text{if } D \leq q \\
[pq] - [s(D - q) + qw_r] & \text{if } D > q
\end{cases}
\]
\[ \Pi(p, q) = \begin{cases} 
[p(g(p)) + v(q - g(p)) - qw_r] & \text{if } D \leq q \\
[pq] - [s(g(p)) - q] + qw_r & \text{if } D > q 
\end{cases} \]

\[ \Pi(p, q) = \begin{cases} 
p(g(p)) + v(q - g(p)) - qw_r & \text{if } D \leq q \\
pq - s(g(p)) - qw_r & \text{if } D > q 
\end{cases} \]

Now put \( g(p) = g \) and define a new parameter \( z = \frac{q}{g(p)} \) i.e. \( q = g \cdot z \), for the multiplicative demand.

\[ \Pi(p, q) = \begin{cases} 
p + v(g - g) - (gz)w_r & \text{if } D \leq q \\
pz - s(g - gz) - (gz)w_r & \text{if } D > q 
\end{cases} \]

Now \( D \leq q \iff g \leq q \iff g \leq z \) and similarly \( D > q \iff g > z \). Thus,

\[ \Pi(z, p) = \begin{cases} 
p + v(g - g) - (gz)w_r & \text{if } \leq \leq z \\
pz - s(g - gz) - (gz)w_r & \text{if } \leq > z 
\end{cases} \]

(6.2) The equation (2) gives the profit function for the buyer in the manufacturer’s currency. Note that the parameter \( q \) is replaced by \( z \).

Now the retailer wants to find the optimal order quantity \( q \) say \( q^* \) for maximizing his expected profit. In order to do this he first finds optimal values of the price \( p \) and the parameter \( z \), that is \( p^* \) and \( z^* \). Then he determines the optimal order \( q^* = z^* \cdot g(p^*) \). Note that the expected profit \( \Pi \) is a function of the random variable \( \varepsilon \) - the demand error.

Thus the buyer’s expected profit is given by,

\[ E[\Pi(z, p)] = \int_{A}^{B} \Pi(z, p) f(\varepsilon) d\varepsilon \]

\[ \Rightarrow E[\Pi(z, p)] = \int_{A}^{Z} \Pi(z, p) f(\varepsilon) d\varepsilon + \int_{Z}^{B} \Pi(z, p) f(\varepsilon) d\varepsilon \] as \( A \leq z \leq B \)

Take \( \varepsilon = u \) for simplicity in (2) and then writing the expected profit we get,

\[ E[\Pi(z, p)] = \int_{A}^{Z} [pgu + vg(z - u) - gzw_r] \cdot f(u) du + \int_{Z}^{B} [pgz - sg(u - z) - gzw_r] \cdot f(u) du \]

\[ = \int_{A}^{Z} [pgu + vg(z - u)] \cdot f(u) du + \int_{Z}^{B} [pgz - sg(u - z)] \cdot f(u) du - gzw_r \left[ \int_{A}^{Z} f(u) du + \int_{Z}^{B} f(u) du \right] \]
\[ \Rightarrow E[\Pi(z, p)] = \int_A^z [pgu + vg(z - u)] \cdot f(u) \, du + \int_z^B [pgz - sg(u - z)] \cdot f(u) \, du - gzw_r \quad (6.3) \]

since \( \int_A^B f(u) \, du = 1. \)

Now we derive an equivalent expression for the equation (3) in the following proposition.

**Preposition-6.1:**

The expected profit of the retailer under isoelastic demand with multiplicative error is,

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

where,

\[ \Lambda = \int_A^z (z - u)f(u) \, du \quad [\text{expected leftovers}] \quad (6.4) \]

and

\[ \Phi = \int_Z^B (u - z)f(u) \, du \quad [\text{expected shortages}] \quad (6.5) \]

Note that \( \Lambda \) and \( \Phi \) both are functions of \( z \). Also \( \mu = \int_A^B uf(u) \, du \) is the expected value of the demand error.

**Proof:**

We have,

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

Let us take \( X = g\mu(p - w_r) \) and \( Y = g[(w_r - v)\Lambda + (p + s - w_r)\Phi] \) for the two parts in the right side of the required result. The first one \( X \) represents risk less profit as it does not contain the randomness term \( \varepsilon \) and the second, \( Y \) gives the loss function. We shall prove the theorem by showing \( E[\Pi(z, p)] = X - Y \) as follows.
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Consider \( X - Y \)
\[
= [(\mu)(p - w_r)] - g[(w_r - v)\Lambda + (p + s - w_r)\Phi] \\
= pg\mu - w_r \cdot g - g(w_r - v)\Lambda - g(p + s - w_r)\Phi \\
= pg \int_{A}^{B} u f(u) du - w_r g \int_{A}^{B} u f(u) du - (gw_r - g) \int_{z}^{A} (z - u) f(u) du \\
= pg \int_{A}^{B} u f(u) du - w_r g \int_{A}^{B} u f(u) du - gw_r \int_{A}^{B} (z - u) f(u) du + g \int_{z}^{A} (z - u) f(u) du \\
= -gp \int_{z}^{A} (u - z) f(u) du - gs \int_{z}^{B} (u - z) f(u) du + gw_r \int_{z}^{B} (u - z) f(u) du \\
= pg \int_{A}^{B} u f(u) du + pg \int_{A}^{B} u f(u) du - w_r g \int_{A}^{B} u f(u) du - gw_r \int_{A}^{B} (z - u) f(u) du + g \int_{z}^{A} (z - u) f(u) du \\
= -gp \int_{z}^{A} (u - z) f(u) du - gs \int_{z}^{B} (u - z) f(u) du + gw_r \int_{z}^{B} (u - z) f(u) du \\
= = \int_{A}^{B} [pgu + gv(z - u)] f(u) du + \int_{z}^{B} [pgu - pg(u - z) - sg(u - z)] f(u) du \\
= -w_r g \int_{A}^{B} u f(u) du - gw_r \int_{A}^{B} (z - u) f(u) du + \int_{A}^{B} (z - u) f(u) du \\
= = \int_{A}^{B} [pgu + gv(z - u)] f(u) du + \int_{z}^{B} [pgu - pg(u - z) - sg(u - z)] f(u) du - w_r g \int_{A}^{B} u f(u) du \\
= gw_r \int_{A}^{B} (z - u) f(u) du \\
= = \int_{A}^{B} [pgu + gv(z - u)] f(u) du + \int_{z}^{B} [pgu - pg(u - z) - sg(u - z)] f(u) du - w_r g \int_{A}^{B} u f(u) du \\
= gw_r \int_{A}^{B} (z - u) f(u) du
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\[ z \int_A^{B} [pgu + gv(z - u)] f(u) du + \int_A^{B} [pgu - pg(u - z) - sg(u - z)] f(u) du - gw \int_A^{B} [u + (z - u)] f(u) du \\
= \int_A^{B} [pgu + gv(z - u)] f(u) du + \int_A^{B} [pgu - pg(u - z) - sg(u - z)] f(u) du - gzw, \int f(u) du \\
= \int_A^{B} [pgu + gv(z - u)] f(u) du + \int_A^{B} [pg - sg(z - u)] f(u) du - gzw, \\
= E [\Pi(z, p)] \\
\]

Hence we have proved that, \( E [\Pi(z, p)] = X - Y \). That is,

\[ E[\Pi(z, p)] = [g\mu(p - w_r)] - g[(w_r - v)\Lambda + (p + s - w_r)\Phi] \] (6.6)

Next we derive the optimal policies for the retailer for maximizing his expected profit.

**Preposition-6.2:**

The optimal order quantity \( q^* \) for the maximum profit of the retailer is given by

\[ q^* = g(p^*) \cdot F^{-1} \left( \frac{p^* + s - w_r}{p^* + s - v} \right) \]

Where \( F^{-1} \) is the inverse cumulative distribution function.

**Proof:**

We have obtained the expected profit of the retailer in (6) as,

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

Clearly \( E \) is a function of two parameters \( z \) and \( p \). Now to maximize the expected profit function we use the Whitin’s method, see section-4.3.4 in chapter-4. According to this method we first keep \( p \) fixed in ‘E’ and then use the second order optimality conditions \( \frac{\partial E}{\partial z} = 0 \) and \( \frac{\partial^2 E}{\partial z^2} < 0 \) and determine the optimal solution \( z = z^* \) as a function of \( p \). Then we substitute this \( z^* \) back in \( E[\Pi(z, p)] \) and obtain \( E \) as function of single variable \( p \) only so that we can obtain the optimal solution for the price \( p = p^* \) using the second order derivative test for extreme values.

Differentiate \( E[\Pi(z, p)] \) partially w.r.t. \( z \),

\[ \frac{\partial E}{\partial z} = 0 - g(w_r - v) \frac{\partial \Lambda}{\partial z} - g(p + s - w_r) \frac{\partial \Phi}{\partial z} \]

But \( \Lambda(z) = \int_A^{z} (z - u) f(u) du \Rightarrow \frac{\partial \Lambda}{\partial z} = \int_A^{z} f(u) du + 0 - 0 = \int_A^{z} f(u) du \)
and
\[ \Phi(z) = \int_{z}^{B} (u - z) f(u) du \Rightarrow \frac{\partial \Phi}{\partial z} = \int_{z}^{B} (-1) f(u) du + 0 - 0 = -\int_{z}^{B} f(u) du \]
\[ \Rightarrow \frac{\partial E}{\partial z} = -g(w_r - v) \int_{z}^{A} f(u) du + g(p + s - w_r) \int_{A}^{B} f(u) du \]
\[ \Rightarrow \frac{\partial E}{\partial z} = -g(w_r - v) \left\{ \int_{z}^{B} f(u) du + \int_{z}^{B} f(u) du - \int_{z}^{B} f(u) du \right\} + g(p + s - w_r) \int_{z}^{B} f(u) du \]
\[ \Rightarrow \frac{\partial E}{\partial z} = -g(w_r - v) \int_{z}^{A} f(u) du + g(w_r - v) \int_{z}^{B} f(u) du + g(p + s - w_r) \int_{z}^{B} f(u) du \]
\[ \Rightarrow \frac{\partial E}{\partial z} = -g(w_r - v) \int_{z}^{B} f(u) du \]
\[ \Rightarrow \frac{\partial E}{\partial z} = -g(w_r - v) + g \int_{z}^{B} (p + s - v) f(u) du \]
\[ \Rightarrow \frac{\partial E}{\partial z} = -g(w_r - v) + g(p + s - v) \int_{z}^{B} f(u) du \]

Now if we use the CDF \( F(z) = \int_{A}^{z} f(u) du \) then we have \( 1 - F(z) = \int_{z}^{B} f(u) du \). Thus,
\[ \frac{\partial E}{\partial z} = -g(w_r - v) + g(p + s - v) [1 - F(z)] \] (6.7)

Again differentiate the above equation w.r.t. \( z \) we get,
\[ \frac{\partial^2 E}{\partial z^2} = (p + s - v) \left[ -\frac{\partial F}{\partial z} \right] \]

But \( F(z) = \int_{A}^{z} f(u) du \Rightarrow \frac{\partial F}{\partial z} = \int_{A}^{z} \frac{\partial (f(u))}{\partial z} du + f(z) \frac{\partial (z)}{\partial z} - f(A) \cdot 0 = f(z) \Rightarrow \frac{\partial F}{\partial z} = f(z) \).
\[ \Rightarrow \frac{\partial^2 E}{\partial z^2} = -(p + s - v) f(z) \] (6.8)

For the maximum expected profit we must have, \( \frac{\partial E}{\partial z} = 0 \) and \( \frac{\partial^2 E}{\partial z^2} < 0 \).
\[ \frac{\partial E}{\partial z} = 0 \Rightarrow -g(w_r - v) + g(p + s - v) [1 - F(z)] = 0, \text{ from (7)}. \]
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\[ g(p + s - v)[1 - F(z)] = g \cdot (w_r - v) \]

\[ F(z) = 1 - \frac{(w_r - v)}{(p + s - v)} \]

\[ F(z) = \frac{p + s - w_r}{p + s - v} \]

\[ z = F^{-1} \left( \frac{p + s - w_r}{p + s - v} \right) = z^* \text{ (say)} \]

Now from equation (8) it is clear that \( \frac{\partial^2 E}{\partial z^2} < 0 \) for any value of \( z \).

Thus the optimal value of \( z \) for maximum profit is,

\[ z^* = F^{-1} \left( \frac{p + s - w_r}{p + s - v} \right) \] (6.9)

Next we substitute this \( z^* \) in equation (6) and find the optimal value of \( p^* \) as discussed in Whitin’s method. So we finally get the optimal order quantity \( q^* \) for the maximum expected profit of the retailer as \( q^* = g(p^*) \cdot z^* \). Thus,

\[ q^* = g(p^*) \cdot F^{-1} \left( \frac{p^* + s - w_r}{p^* + s - v} \right) \] (6.10)

Where \( F^{-1} \) is the inverse cumulative distribution function. Hence the result is proved.

Finally, recall that for manufacturer his purchase cost is \( c \) and his selling price when the retailer bears the risk is \( w \). So the manufacturer’s profit when the retailer bears the exchange rate risk is defined as,

\[ \Pi_m = \left[ (\text{selling price of the manufacturer}) - (\text{cost of purchase of the manufacturer}) \right] \times \text{no. of units sold.} \]

That is \( \Pi_m = (w - c)q^* \).

### 6.3.2 The multiplicative model for the risk taker manufacturer

In this model we assume that the manufacturer bears the exchange rate risk and the retailer does not, under the isoelastic demand with multiplicative error. So in this case the retailer will have to pay \( w_r \) per unit at any point of time in his currency. So the purchase cost of the retailer will be \( w \) only at any time, in the manufacturer’s currency. But as the manufacturer bears the risk, he will get \( \frac{w_r}{r(1 + \varepsilon_r)} = w_m \text{ (say)} \) per unit, in his currency according to the existing rate i.e. F.E.R., on the settlement day.
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Now the retailer will choose the selling price $p$ and the order quantity $q$ so as to maximize
his expected profit. The profit function for the retailer is denoted by $\Pi(p, q)$ and is given
by,

$$\Pi(p, q) = \text{[Revenue from the q items in the inventory]} - \text{[Expenses for the q items in the}
\text{inventory]}$$

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

(6.11)

Then it can be shown that the expected profit of the retailer when the manufacturer bears
the risk is obtained just by replacing $w_r$ by $w$ in (6). Thus we have

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

Where $z = q/g(p)$

Further maximizing the expected profit we get the similar results as in the above model
where the buyer bears the risk.

The optimal order of the retailer is,

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

At the end, recollecting that for the manufacturer, his purchase cost is $c$ and his selling
price when he is bearing the risk is $w_m$. So the manufacturer’s profit when the he bears
the exchange rate risk is defined as,

$$\Pi_m = [(\text{selling price of the manufacturer}) - (\text{cost of purchase of the manufacturer})] \times \text{no. of}
\text{units sold.}$$

That is,

$$\Pi_m = (w_m - c)q^* = \left[\frac{wr}{r(1 + \epsilon_r)} - c\right] q^*$$

(6.12)

6.4 Summary

We have elaborated the foreign exchange rate risk model under isoelastic demand with
multiplicative error, when the buyer or the seller any one of them undertakes the exchange
rate risk. We summarize all the key terms and the optimal policies of the two models in
the table 6.1 given below. The model’s sensitivity analysis is carried out in the chapter 8
and 9 under various exchange rate error distributions like uniform, normal and beta.
<table>
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<th>The demand model</th>
<th>Buyer bears the risk</th>
<th>Seller bears the risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand equation</td>
<td>( D(p,q) = g(p) \cdot \xi = (ap^{-b}) \cdot \xi )</td>
<td></td>
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<table>
<thead>
<tr>
<th>Buyer’s purchase cost</th>
<th>( w_r = wr(1+\xi_r)/r = w(1+\xi_r) )</th>
<th>( w )</th>
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<tr>
<td>Seller’s selling price</td>
<td>( w )</td>
<td>( w_m = \frac{wr}{r(1+\xi_r)} = \frac{w}{(1+\xi_r)} )</td>
</tr>
</tbody>
</table>

| Expected profit of buyer \( E[\Pi(z,p)] \) | \( [g\mu(p-w)] - g[(w_r-v)\Lambda + (p+s-w)\Phi] \) | \( [g\mu(p-w)] - g[(w-v)\Lambda + (p+s-w)\Phi] \) |

| Optimum Order quantity \( q^* \) | \( q^* = g(p^*) \cdot F^{-1} \left( \frac{p+s-w_r}{p+s-v} \right) \) | \( q^* = g(p^*) \cdot F^{-1} \left( \frac{p+s-w}{p+s-v} \right) \) |

| Expected profit of seller \( \Pi_m \) | \( (w-c)q^* \) | \( (w_m-c)q^* \) |

Table 6.1: IDME model