

Exchange Rate Volatility and Dumping: A Real Options Approach

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Abstract

Ever since the 1980s, anti-dumping cases have been increasing considerably around the world. The distinctive features of these dumping cases are that they often occur in international oligopoly industries, and that the number of dumping cases has fluctuated sharply over time. This paper develops a real options model to show that exchange rate uncertainty is one of the most important factors accounting for these phenomena. Our model predicts that the higher the volatility is of the exchange rate, or the larger the sunk costs are of investment, the more likely exporting firms will dump their products onto foreign markets. These results are consistent with the above-mentioned features of dumping cases.

Keywords: exchange rate volatility, dumping, real options approach

JEL Classification: F13, F31, G13

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1. Introduction

Ever since the 1980s, anti-dumping cases have been increasing considerably around the world. The distinctive features of these anti-dumping cases are that they often occur in international oligopoly industries, such as steel, chemical, and hi-tech industries, and that the number of anti-dumping cases has fluctuated sharply over time. The purpose of this paper is to develop a real options model to show that exchange rate uncertainty is one of the most important factors accounting for these phenomena.

Dumping is said to occur if a foreign producer sells its output in an export market either at a price below what it charges in its domestic market or in third countries, or at a price that does not permit the recovery of all production costs. Why does a firm engage in dumping? Modern dumping theory has attributed it to uncertainty since many contemporary problems seem related to changes in technological and market conditions (for instance, Ethier (1982) and Hillman and Katz (1986)). However, the above-maximized net present value (NPV) analysis of dumping firms always ignores the flexibility of production. In fact, the characteristics of investment expenditure include uncertainty about future payoffs, partial irreversibility, and ability to wait.

The real options approach highlights the importance of flexibility. This means a firm can create the value of waiting when a firm faces uncertainty over future demand. The real options approach suggests that operational flexibility enables the firm to selectively exploit favorable currency movements in order to maximize profit potential and minimize the impact of adverse currency movements and downside risk.

Wares (1977) first proposes a theory of *exchange dumping*. It is argued that dumping is a lag response of the export price with respect to the volatility of exchange rate. Baldwin and Krugman (1989) and Dixit (1989) formalize the idea of Wares (1977) with a real options approach. They view the opportunity for a firm to be

present in a foreign market as like a financial option. The uncertainty of exchange rates makes the cost of exports fluctuate when determining current production levels. The reason is that a volatile exchange rate affects production by making part of what the firm spends to produce as an irreversible investment. The irreversible investment cost might induce the firm to sell at a price below its production cost on the export market.

In a model with two national markets, Friberg (2001) demonstrates that the real exchange rate can affect the incentive to create a barrier of arbitrage since it influences the optimal prices on the home market and foreign market. In Friberg's model, sunk costs of market segmentation imply that if the variability of the real exchange rate is larger, then the option to segment markets is more valuable.

Friberg (2001) does not consider operational flexibility arising from multi-stage investment decisions. A firm usually invests and produces to sell domestically in the first stage, and then exports to foreign markets in the second stage. This paper extends Friberg's (2001) model to examine a firm's optimal dumping strategy when the firm makes sequential investment decisions under exchange rate uncertainty. We use a sequential real options model to illustrate the determinants of the firm's optimal investment, production decisions, as well as optimal operating decision to dump onto foreign markets.

The remainder of this paper proceeds as follows. A theoretical framework of investment under exchange rate uncertainty is developed and the optimal thresholds of sequential investments are derived in Section 2. Section 3 then examines the impacts

of exchange rate volatility and other parameters on the firm's investment, exporting, and pricing behaviors. The final section concludes.

2. The Model

Consider a multinational firm which produces a single product. The firm faces a sequential investment problem. In the first stage, it determines if it will incur a sunk cost I_1 so as to establish a plant to produce and sell on the domestic market. In the second stage, the firm has established the plant, and it has to decide if it will incur an additional sunk cost I_2 ¹ to export its product to the foreign markets.

This problem can be investigated with a sequential real options model. At time t_1 , the firm faces a binary choice: to build the plant or not. If it chooses to build the plant, then it pays I_1 to exercise the option to produce and sell on the domestic market, and the firm obtains an option to export its product to the foreign markets in the future at the same time. After some time, at time T_1 ($T_1 > t_1$), the firm faces another binary choice: to export or not to export. If it determines to export, then it means that it pays I_2 to exercise the option to sell on the foreign markets. Since it is a sequential investment decision problem, the model has to be solved backward. We first derive the investment threshold for the second stage and then solve the threshold

¹ To export a product to a foreign market, a firm has to spend a considerable amount on advertising and establishing distributional channels, and part of those expenditures represents a sunk cost.

for the first stage.

2.1 Optimum Timing of Export

Suppose that in the second stage the firm has already established its plant, and the firm can determine whether to export its product to another country or not. To simplify our analysis, we assume that the firm is the only producer in the world. If the firm decides to export, then it faces the following inverse demand functions in the domestic market and foreign market, respectively, at time t (for simplicity, the subscript of t for the variables is suppressed hereafter):

$$P_d = Q_d^{-\frac{1}{\varepsilon_d}} \quad (1)$$

and

$$P_f = Q_f^{-\frac{1}{\varepsilon_f}}. \quad (2)$$

Here, subscript d denotes the domestic market and f is the foreign market, P 's are prices, Q 's are quantities of the commodity sold, and ε 's are the price elasticities of demand. Assume that P_d is in units of domestic currency and P_f is in units of foreign currency.

The objective of the firm is to choose Q_d and Q_f so as to maximize its total profits π :

$$\begin{aligned}
\text{Max}_{Q_d, Q_f} \pi(P_d, P_f, Q_d, Q_f, Y) &= P_d \cdot Q_d + P_f \cdot Q_f \cdot Y - w(Q_d + Q_f) \\
&= Q_d^{1-\frac{1}{\varepsilon_d}} + Q_f^{1-\frac{1}{\varepsilon_f}} \cdot Y - w(Q_d + Q_f),
\end{aligned} \tag{3}$$

where w is the constant marginal cost of production, and Y is the exchange rate expressed in units of home currency per foreign currency. Suppose that Y is uncertain and follows an exogenously geometric Brownian Motion process:

$$\frac{dY}{Y} = \alpha dt + \sigma dz. \tag{4}$$

where α is the average change rate and σ is the standard deviation of Y in every unit of time interval, while dz is an increment of the Wiener process.

The first-order necessary conditions for the profit-maximization problem in equation (3) are:

$$\frac{\partial \pi}{\partial Q_d} = \left(1 - \frac{1}{\varepsilon_d}\right) Q_d^{-\frac{1}{\varepsilon_d}} - w = 0 \tag{5}$$

$$\frac{\partial \pi}{\partial Q_f} = \left(1 - \frac{1}{\varepsilon_f}\right) Q_f^{-\frac{1}{\varepsilon_f}} - w = 0. \tag{6}$$

From equations (5) and (6), we can derive optimum quantities sold on the domestic market and foreign market, respectively, as follows:

$$Q_d^* = \left(\frac{1 - \frac{1}{\varepsilon_d}}{w} \right)^{\varepsilon_d} \tag{7}$$

$$Q_f^* = \left(\frac{(1 - \frac{1}{\varepsilon_f})Y}{w} \right)^{\varepsilon_f}. \quad (8)$$

Substituting equations (7) and (8) into the profit function, we have:

$$\pi^* = A + B \cdot Y^{\varepsilon_f}, \quad (9)$$

where

$$A = \frac{1}{\varepsilon_d} \left[\frac{1 - \frac{1}{\varepsilon_d}}{w} \right]^{\varepsilon_d - 1} \quad (10)$$

$$B = \frac{1}{\varepsilon_f} \left[\frac{1 - \frac{1}{\varepsilon_f}}{w} \right]^{\varepsilon_f - 1}. \quad (11)$$

Equation (9) indicates that the profits of the monopoly firm are affected by the movements in the exchange rate, besides other factors, such as w , ε_d , and ε_f .

Define the value of the export option by $F_2(Y)$:

$$F_2(Y) = \text{Max}_{t_2 \in [T_1, T_2]} E_{T_1} \left\{ [V(Y) - I_2, 0] e^{-\mu t_2} \right\}, \quad (12)$$

where E_{T_1} is the conditional expectation operator at time T_1 , $V(Y)$ is the value of the investment project, μ is the risk-adjusted discount rate, t_2 is the optimal timing of the exports, and T_2 is the time at which the firm stops exporting. Equation (12) indicates that when the discounted present value of the investment project net of the sunk cost is positive beyond a certain threshold value of an exchange rate level, the firm will start to export.

Lemma 1: Suppose that exchange rate risk can be hedged completely through capital markets. Then, $V(Y)$ has to satisfy the following differential equation:

$$\frac{1}{2}\sigma^2 Y^2 V''(Y) + (r - \delta)YV'(Y) - rV(Y) + \pi^* = 0, \quad (13)$$

where r is a risk-free interest rate, and $\delta = \mu - \alpha$.²

Proof: See Appendix.

Lemma 2:
$$V(Y) = \frac{A}{r} + \frac{B \cdot Y^{\varepsilon_f}}{\Delta_2} \quad (14)$$

where

$$\Delta_2 = r - (r - \delta)\varepsilon_f - \frac{1}{2}\sigma^2\varepsilon_f(\varepsilon_f - 1) \quad (15)$$

Proof: See Appendix.

To solve for $F_2(Y)$ and the optimum threshold value of exchange rate Y_2^* in the second stage, notice that $F_2(Y)$ has to satisfy the following differential equation:³

$$\frac{1}{2}\sigma^2 Y^2 F_2''(Y) + (r - \delta)YF_2'(Y) - rF_2(Y) = 0, \quad (16)$$

subject to the following border conditions:

$$F_2(0) = 0 \quad (17)$$

$$F_2(Y_2^*) = V(Y_2^*) - I_2 \quad (18)$$

$$F_2'(Y_2^*) = V'(Y_2^*). \quad (19)$$

² See Dixit and Pindyck (1994), p.148.

³ See Dixit and Pindyck (1994), pp.140-141.

Equation (17) implies that if the export price is zero, then the value of the export option is also zero. Equation (18) is the value matching condition, which indicates that the value of the export option is equal to the net value of the project. Equation (19) is the smooth-pasting condition, which suggests that at the point of optimum timing F_2 has to be continuous, smooth, and have the same slope as $V(Y)$.

Proposition 1: The value of the export option is given by:

$$F_2(Y) = D_2 \cdot Y^{\beta_2}, \quad (20)$$

where

$$D_2 = \frac{\varepsilon_f}{\varepsilon_f - 1} \left(\frac{A}{r} - I_2 \right) Y_2^{* \frac{\beta_2}{\varepsilon_f}} > 0 \quad (21)$$

$$Y_2^* = \left[\frac{(I_2 - A/r) \Delta_2 \beta_2}{B(\beta_2 - \varepsilon_f)} \right]^{\frac{1}{\varepsilon_f}} \quad (22)$$

and

$$\beta_2 = \frac{1}{2} - \frac{(r - \delta)}{\sigma^2} + \sqrt{\left(\frac{1}{2} - \frac{(r - \delta)}{\sigma^2} \right)^2 + \frac{2r}{\sigma^2}} > 1. \quad (22)$$

Proof: Applying the solving procedure in Dixit and Pindyck (1994, p. 141)), it is straightforward to obtain the above result.

When the actual exchange rate level exceeds its optimum threshold, $Y \geq Y_2^*$, the firm exercises its export option. Equations (20), (21), and (22) reveal that the value of

export option $F_2(Y)$ is greater than zero. This implies that the traditional net present value approach underestimates the optimum threshold of investment, because it ignores the value of flexibility when facing uncertainty of investment with sunk costs.

2.2 Optimum Timing of Plant Investment

Given $F_2(Y)$ and Y_2^* derived in the above subsection for the firm's second-stage problem, we next calculate the value of the option for plant investment, $F_1(Y)$, and optimum threshold value Y_1^* in the first stage. The value of the option for plant investment can be written as follows:

$$F_1(Y) = \text{Max}_{t_1 \in [0, T_1]} E_0 \left\{ \left[F_2(Y) - I_1, 0 \right] e^{-\mu t_1} \right\}, \quad (23)$$

where E_0 is the conditional expectation operator at time 0, t_1 is the optimal timing of investment, T_1 is the time at which the firm stops investing, and I_1 is the cost of plant investment.

The option for plant investment $F_1(Y)$ has to satisfy the following differential equation:⁴

$$\frac{1}{2} \sigma^2 \beta_1^2 F_1''(Y) F_2^2(Y) + (r - \delta) F_1'(Y) F_2(Y) + F_2(Y) - r F_1(Y) = 0, \quad (24)$$

⁴ The procedure to solve this differential equation is similar to equation (16) in the second-stage problem..

subject to following border conditions:

$$F_1(0) = 0 \quad (25)$$

$$F_1(Y_1^*) = F_2(Y_1^*) - I_1 \quad (26)$$

$$F_1'(Y_1^*) = F_2'(Y_1^*) . \quad (27)$$

Proposition 2: The value of the plant investment t option is given by:

$$F_1(Y) = D_1 \cdot F_2(Y)^{\beta_1} . \quad (28)$$

where

$$D_1 = \frac{I_1}{(\beta_1 - 1)} \left[D_2 Y_1^{*\beta_2} \right]^{-\beta_1} . \quad (29)$$

$$Y_1^* = \left[\frac{\beta_1 \Delta_1}{(1 - \Delta_1) D_2 (\beta_1 - 1)} I_1 \right]^{\frac{1}{\beta_2}} . \quad (30)$$

$$\beta_1 = \frac{1}{2} - \frac{(r - \delta)}{\sigma^2 \beta_2^2} + \sqrt{\left(\frac{1}{2} - \frac{(r - \delta)}{\sigma^2 \beta_2^2} \right)^2 + \frac{2r}{\sigma^2 \beta_2^2}} > 1 . \quad (31)$$

$$\Delta_1 = \delta .$$

Proof: See Appendix.

3. Comparative Statics

In this section the impacts of exchange rate volatility and other parameters on the firm's investment, exporting, and pricing behaviors are examined.

Proposition 3: The higher the exchange rate volatility is, the less likely the firm is

to export its product - that is, $\frac{\partial Y_2^*}{\partial \sigma} > 0$.

Proof: See Appendix.

The economic reason behind the result of Proposition is intuitively clear. With sunk costs of exporting, the value of the option to export is larger when the exchange rate volatility is higher. As a result, the firm is less willingly to sell on a foreign market.

Proposition 4: The exchange rate volatility and export price are inversely related - that is, $\frac{\partial P_f}{\partial \sigma} < 0$.

Proof: Notice that

$$\frac{\partial P_f}{\partial Q_f} < 0, \frac{\partial Q_f}{\partial Y} \Big|_{Y=Y_2^*} > 0^5, \text{ and } \frac{\partial Y_2^*}{\partial \sigma} > 0.$$

Therefore, we have:

$$\frac{\partial P_f}{\partial \sigma} = \frac{\partial P_f}{\partial Q_f} \cdot \frac{\partial Q_f}{\partial Y} \Big|_{Y=Y_2^*} \cdot \frac{\partial Y_2^*}{\partial \sigma} < 0. \quad (34)$$

Proposition 4 suggests that the higher the exchange rate volatility is, the more likely the firm is to sell at a lower price on the foreign market. The economic intuition is that, as shown in Proposition 3, when the firm faces a higher volatility of exchange rate, it requires a higher level of exchange rate to induce it to sell on the foreign

⁵ Since Y is a geometric Brownian process, which is not differentiable, we evaluate the effect of the exchange rate uncertainty on the output level at the threshold point of the second stage.

market. Consequently, the firm exports its product to the foreign market only if export becomes more profitable. It implies that its equilibrium level of export will be higher so as to lower the equilibrium price on the foreign market.

From Equations (1) and (7), it is clear that domestic price P_d is deterministic. Thus, Proposition 4 implies that an increase in exchange rate volatility widens the price difference between a firm's domestic price and its export price. Therefore, combining Propositions 3 and 4, we can conclude that the higher the volatility is of the exchange rate, the more likely the firm will dump its product on a foreign market.

Proposition 5: The higher the cost of plant investment is, the less likely the firm is

to export its product - that is, $\frac{\partial Y_2^*}{\partial I_1} > 0$.

Proof: It is obvious from Equation (22).

The economic reason behind the result of Proposition 5 is also intuitively clear. After incurring a sunk cost of plant investment, the firm not only can sell on the domestically but also gets an option to export in the future. When the cost of plant investment is higher, the value of the option to export is larger with a higher exchange rate volatility. As a result, the firm is less willingly to sell on a foreign market.

Proposition 6: The cost of plant investment and export price are inversely related -

that is, $\frac{\partial P_f}{\partial I_1} < 0$.

Proof: Notice that:

$$\frac{\partial P_f}{\partial Q_f} < 0, \frac{\partial Q_f}{\partial Y} \Big|_{Y=Y_2^*} > 0, \text{ and } \frac{\partial Y_2^*}{\partial I_1} > 0.$$

Thus, we have:

$$\frac{\partial P_f}{\partial I_1} = \frac{\partial P_f}{\partial Q_f} \cdot \frac{\partial Q_f}{\partial Y} \Big|_{Y=Y_2^*} \cdot \frac{\partial Y_2^*}{\partial I_1} < 0. \quad (35)$$

Proposition 6 indicates that the industries characterized with high fixed costs are more likely to export at lower prices. This implies that those industries are more likely to dump their products onto foreign markets.

4. Conclusion

This paper develops a real options model to examine a firm's optimal dumping strategy when the firm makes sequential investment decisions under exchange rate uncertainty. It is shown that an increase in exchange rate volatility widens the price difference between a firm's domestic price and its export price. In other words, the dumping behavior is more likely to occur when the exchange rate fluctuates more sharply. In addition, our model predicts that industries characterized with high fixed costs are more likely to export at lower prices, meaning that those industries are more likely to dump their products onto foreign markets. These results are consistent with the observed characteristics of anti-dumping case around the world.

Appendix

Proof of Lemma 1:

At time t , we create a portfolio with one unit of the project and n units of a short sale of foreign currency so that this portfolio is risk-free. To hold this portfolio in a very short interval of time $(t, t + dt)$, the investor obtains a yield or profit Ydt at dt . However, a dividend $\delta \cdot Ydt$ is paid out so that the portfolio holder receives $(Y - n\delta Y)dt$. The project creates profit flow π^* . The capital gain from selling this portfolio is:

$$dV - ndY = \{ \alpha Y[V'(Y) - n] + \frac{1}{2} \sigma^2 Y^2 V''(Y) \} dY + Y[V'(Y) - n] \sigma dz + \pi^* dt. \quad (A1)$$

If we set $n = V'(Y)$, then the random term dz disappears. As a result, this portfolio is risk-free. Therefore, (A1) becomes:

$$\{ Y - \delta Y V'(Y) + \frac{1}{2} \sigma^2 Y^2 V''(Y) + \pi^* \} dt. \quad (A2)$$

Let (A2) be equal to the risk-free rate of return, $r[V(Y) - n(Y)]dt$. We hence have the differential equation in Equation (13):

$$\frac{1}{2} \sigma^2 Y^2 V''(Y) + (r - \delta) Y V'(Y) - rV(Y) + \pi^* = 0.$$

Proof of Lemma 2:

The solution to equation (13) consists of two parts: a general solution and a

particular solution. First, we guess that the general solution takes the form:

$V_G(Y) = (B \cdot Y^{\varepsilon_f}) / \Delta_2$. Solving the following equation:

$$\frac{1}{2} \sigma^2 Y^2 V''(Y) + (r - \delta) Y V'(Y) - r V(Y) = 0,$$

we obtain

$$\Delta_2 = r - (r - \delta) \varepsilon_f - \frac{1}{2} \sigma^2 \varepsilon_f (\varepsilon_f - 1).$$

Furthermore, we observe that the particular solution turns out to be $V_p(Y) = A/r$.

Therefore, the solution to Equation (13) is

$$V(Y) = V_p(Y) + V_G(Y) = \frac{A}{r} + \frac{B \cdot Y^{\varepsilon_f}}{\Delta_2}.$$

Proof of Proposition 1:

Substituting Equation (24) into Equation (28), we obtain:

$$\frac{1}{2} \sigma^2 \beta_2^2 \beta_1 (\beta_1 - 1) + (r - \delta) \beta_1 - r = 0,$$

where

$$\beta_1 = \frac{1}{2} - \frac{(r - \delta)}{\sigma^2 \beta_2^2} + \sqrt{\left(\frac{1}{2} - \frac{(r - \delta)}{\sigma^2 \beta_2^2} \right)^2 + \frac{2r}{\sigma^2 \beta_2^2}} > 1.$$

Since the particular solution is $\frac{F_2}{\Delta_1}$, we have:

$$F_1(Y) = \frac{F_2}{\Delta_1} + D_1 \cdot F_2^{\beta_1},$$

where $\Delta_1 = \delta$. Substituting the border conditions in Equations (25)-(27) into equation

(33), we obtain:

$$D_1 = \frac{I_1}{(\beta_1 - 1)} \left[D_2 Y_1^{*\beta_2} \right]^{-\beta_1}. \quad (29)$$

Finally, substituting Equation (29) into Equation (26), we can derive the exchange rate threshold in the first stage as follows:

$$Y_1^* = \left[\frac{\beta_1 \Delta_1}{(1 - \Delta_1) D_2 (\beta_1 - 1)} I_1 \right]^{\frac{1}{\beta_2}}.$$

Proof of Proposition 3:

Recall that

$$Y_2^* = \left[\frac{(I_2 - A/r) \Delta_2 \beta_2}{B(\beta_2 - \varepsilon_f)} \right]^{\frac{1}{\varepsilon_f}},$$

where $\Delta_2 = r - (r - \delta) \varepsilon_f - \frac{1}{2} \sigma^2 \varepsilon_f (\varepsilon_f - 1)$.

$$\beta_2 = \frac{1}{2} - \frac{(r - \delta)}{\sigma^2} + \sqrt{\left(\frac{1}{2} - \frac{(r - \delta)}{\sigma^2} \right)^2 + \frac{2r}{\sigma^2}} > 1.$$

From Dixit and Pindyck (1994, p.144), we know that:

$$\frac{\partial \beta_2}{\partial \sigma} < 0, \text{ and } \frac{\partial \Delta_2}{\partial \sigma} = -\sigma \cdot \varepsilon_f (\varepsilon_f - 1) < 0 \text{ if } \varepsilon_f > 1.$$

Thus, we have:

$$\begin{aligned} \frac{\partial Y_2^*}{\partial \sigma} &= \frac{1}{\varepsilon_f} \left[\frac{(I_2 - A/r) \Delta_2 \beta_2}{B(\beta_2 - \varepsilon_f)} \right]^{\frac{1}{\varepsilon_f} - 1} \\ &\quad \left\{ \frac{(I_2 - A/r) \beta_2}{B(\beta_2 - \varepsilon_f)} \frac{\partial \Delta_2}{\partial \sigma} + \frac{\Delta_2 (I_2 - A/r) \beta_2 \varepsilon_f}{B[(\beta_2 - \varepsilon_f)]^2} \frac{\partial \beta_2}{\partial \sigma} \right\} > 0. \end{aligned}$$

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