The Impact of Exchange Rate Movements on Dumping Activity: Theory and Evidence

Kun-Ming Chen[*]

Department of International Business, National Chengchi University

and

Chia-Ching Lin

Department of Managerial Economics, Nanhua University

ABSTRACT

This paper develops a real options model to investigate the relationship between exchange rate movements and the occurrence of price dumping. Our results reveal that the effect of exchange rate volatility on the probability of dumping occurrence is ambiguous, depending on the level of exchange rate. The appreciation of the importing country's currency tends to have a positive impact on the probability of dumping occurrence if the exchange rate level is not too high. However, if the exchange rate level is unusually high, this relationship might lessen or even reverse. By contrast, exchange rate volatility tends to be positively related to the probability of dumping occurrence if the exchange rate level is high or low enough. Otherwise, its positive relationship might weaken. The number of antidumping cases filed from 1980 to 2005 by U.S. firms is used to test the validity of our theoretical results. Our empirical evidence is consistent with the theory. These results suggest that it is essential to take into account the possible asymmetry in investigating the relationship between exchange rate movements and dumping activities.

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1. Introduction

Ever since the formation of General Agreement on Tariffs and Trade (GATT) in 1947, import tariffs have been gradually reduced to a very low level, following eight rounds of multilateral trade negotiation. Consequently, many countries around the world have increasingly relied on non-tariff trade barriers (NTBs) as a substitute for tariff protection. Particularly, over the past three decades, an antidumping (AD) policy has emerged as the most serious and widespread impediment to trade, and consequently many recent papers have examined the determinants of dumping activity. Previous studies focus on the effects of industry-specific factors in determining dumping activity. The impact of macroeconomic factors, especially the exchange rate, has become a new focal point in recent studies.[1] However, there still have been few theoretical studies analyzing the relationship between macroeconomic factors and dumping activity in general, and the impact of exchange rate movements on dumping activity in particular.

Regarding the effect of exchange rate on dumping, empirical evidence is still mixed. For example, an early study by Feinberg (1989) finds that an appreciation of an importing country's currency deters the dumping activity while most recent studies, such as Stallings (1993), Leidy (1997), Knetter and Prusa (2003), Irwin (2004), Feinberg (2005), Sadni Jallab et al. (2006), indicate that an appreciation of an importing country's currency tends to stimulate the dumping activity. In addition, the possible impact of exchange rate uncertainty

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[1] See Aggarwal (2004: 1044).

on dumping activity is still unexplored. To fill this gap in the literature, the purpose of this paper is to investigate the effects of exchange rate movements on dumping activity both theoretically and empirically.

Dumping has been regarded as international price discrimination (so-called price dumping) by many economists, which occurs in imperfectly competitive industries. However, Dixit (1989), using a real options model to analyze entry and exit decisions under uncertainty, shows that even small firms can practice dumping in the sense of charging a price abroad below its cost of production plus the delivery to the export market (so-called cost dumping), irrespective of the market structure.[2]

This paper extends the real options model of Dixit (1989) to investigate the occurrence of price dumping under exchange rate uncertainty. In particular, our model demonstrates how exchange rate movements might affect a multinational firm's exit decision as well as its pricing strategy in an international imperfectly competitive industry, and thus affect the probability of the occurrence of price dumping. The number of antidumping filings from 1980 to 2005 in the United States will be used to test the validity of our theoretical results. We find the effects of exchange rate level, its trend, and its volatility on dumping occurrence seem to be asymmetric, depending on the expected level of exchange rate. These empirical results are consistent with our theory.

The remainder of this paper proceeds as follows. Section 2 extends the real options

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[2] See Dixit (1989: 631).

model of Dixit (1989) to the setting of imperfect competition. Section 3 examines the impact of exchange rate movements on a multinational firm's dumping behavior. Based on the theoretical framework, an empirical model is developed and an estimation method is discussed in Section 4. Section 5 presents empirical results, and the final section concludes.

2. A real options model of dumping under exchange rate uncertainty

Suppose that there are two countries, domestic country d and foreign country f, with one producing firm in each country. The firms produce differentiated products. For simplicity, suppose that the firm in the domestic country (Firm 1) can sell in the home country as well as export its product to the foreign country, whereas the firm in the foreign country (Firm 2) can sell in the market of its own country only. Suppose that market demands are linear functions of prices.[3] Let q_{1d} and p_{1d} respectively denote quantity and price in the domestic country. Let q_{1f} and q_{2f} (p_{1f} and p_{2f}) denote the quantities (prices) of the firms in the foreign country where subscripts 1 and 2 represent the domestic and the foreign firm, respectively. The demand function in the domestic country is:

$$q_{1d} = a_d - p_{1d}. \tag{1a}$$

Similarly, the demand functions in the foreign country are:

$$q_{1f} = a_f - p_{1f} + b \cdot p_{2f}, \tag{1b}$$

$$q_{2f} = a_f - p_{2f} + b \cdot p_{1f}. \tag{1c}$$

In this paper, we do not consider the case where goods are complements (that is, the case in

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[3] The linear demand function is a general setting in this area of literature, e.g., Smith (1987), Motta (1992), and Anderson et al. (1995).

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which *b* is non-negative). It is also assumed that $0 < b < 1$, indicating that own price effects are larger than cross price effects.

Since this paper focuses on the case of price-dumping, without loss of generality, the production costs are set equal to zero. Suppose that Firm 1 needs to pay a tariff τ, in terms of foreign currency per unit of exports. Moreover, suppose that the firms play a price competition game, and they announce their prices simultaneously. The exchange rate *R*, expressed in units of home currency per foreign currency, is assumed to follow an exogenously geometric Brownian motion:

$$\frac{dR}{R} = \mu \cdot dt + \sigma \cdot dz,$$

(2)

where μ is the growth rate of the exchange rate; σ is the volatility of the exchange rate; *t* is the time path and *z* is a Wiener process.

In each period, the profit functions for these firms are:

$$\pi_1 = \pi_{1d} + \pi_{1f}$$
$$= p_{1d}(a_d - p_{1d}) + (p_{1f} - \tau)(a_f - p_{1f} + b \cdot p_{2f})R,$$

(3a)

$$\pi_2 = p_{2f}(a_f - p_{2f} + b \cdot p_{1f}),$$

(3b)

where π denotes the total profit. It is easy to show that the equilibrium price, quantity, and profit of Firm 1 in the home market are:

$$p_{1d}^* = \frac{a_d}{2}, \quad q_{1d}^* = \frac{a_d}{2}, \text{ and } \pi_{1d}^* = \frac{a_d^2}{4},$$

(4)

where superscript * represents the equilibrium outcome. The equilibrium prices of Firms 1 and 2 respectively in the host market are:

$$p_{1f}^* = \frac{a_f(2+b)+2\tau}{4-b^2},$$ (5a)

and

$$p_{2f}^* = \frac{a_f(2+b)+b\tau}{4-b^2}.$$ (5b)

The equilibrium quantities are:

$$q_{1f}^* = \frac{a_f(2+b)-(2-b^2)\tau}{4-b^2},$$ (6a)

and

$$q_{2f}^* = \frac{a_f(2+b)+b\tau}{4-b^2}.$$ (6b)

The equilibrium profit of Firm 1 is:

$$\pi_{1f}^* = \frac{\left[a_f(2+b)-(2-b^2)\tau\right]^2 R}{\left(4-b^2\right)^2}.$$ (7)

In order to ensure that all equilibrium quantities are positive, we assume that:

$$a_f(2+b) > (2-b^2)\tau.$$ (8)

Finally, the second-order conditions are:

$$\frac{\partial^2 \pi_1}{\partial p_{1d}^2} = -2, \ \frac{\partial^2 \pi_1}{\partial p_{1f}^2} = -2R, \text{ and } \ \frac{\partial^2 \pi_2}{\partial p_{2f}^2} = -2.$$

It is obvious that the second-order conditions are all satisfied.

Suppose that Firm 1 needs to pay a fixed cost F_1, such as advertising expenditures, to maintain its foreign operation. In addition, suppose that it has an option to stop exporting to the foreign country; however, it must pay lump-sum exit costs K_1 if it decides to exit the

market.[4] The profit flows in terms of the home country's currency fluctuate due to exchange rate movements. If its net profit becomes negative, then the firm may consider exiting the foreign market. Therefore, in each period Firm 1 faces a binary decision problem as follows:

$$V(R) = \max \left\{ \xi_{1d}^*(R) - K_1, \pi_{1d}^* + \pi_{1f}^* - F_1 + \frac{1}{1+\Delta t \rho} E[V(R')|R] \right\}, \tag{9}$$

where V is the optimal expected net present value; $\xi_{1d}^*(R) = a_d^2/4\rho$ represents the expected present value for domestic sales; ρ is the firm's private discount rate; Δt is the time interval; K_1 is the exit cost expressed in the home country's currency; and R' is the exchange rate in period $t+1$. The former term on the right-hand side, $\xi_{1d}^*(R) - K_1$, is the net value after exiting the foreign market, and the latter term, $\pi_{1d}^* + \pi_{1f}^* - F_1 + (1+\Delta t \rho)^{-1} E[V(R')|R]$, is the value of exporting and keeping the right to exit at the next period.

The decision problem of Firm 1 is to choose an optimal timing to exit the foreign market. Since the profit from exporting in this model is an increasing function in R, there is a cutoff point, R_E^*, at which if $R < R_E^*$, then the net exit value is greater than the value of staying at the foreign market, thus causing the firm to exit the foreign market.[5] Using value-matching and smooth-pasting conditions, we have:

$$R_E^* = \frac{\rho - \mu}{A} \frac{\alpha}{1+\alpha} \left(\frac{F_1}{\rho} - K_1 \right),^{6} \tag{10}$$

where $\alpha = \sigma^{-2}[(\mu - 0.5\sigma^2) + \sqrt{(\mu - 0.5\sigma^2)^2 + 2\sigma^2 \rho}] > 0$; $A = \frac{[a_f(2+b)-(2-b^2)\tau]^2}{(4-b^2)^2} > 0$. To ensure that there is a possibility for a firm to exit the foreign market, we assume that $F_1/\rho - K_1 > 0$.

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[4] K_1 can be less than zero if the scrap value of the firm is positive.
[5] See Dixit and Pindyck (1994: 128).
[6] For the purpose of convergence, we assume $\rho > \mu$.

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3. Comparative statics

An AD duty might be imposed on the dumping firm if it is undertaking a dumping activity and thereby causing material injury on the domestic firms in the importing country. Whether or not a firm is undertaking a dumping activity is determined by the so-called dumping margin. Here, the dumping margin, *DM*, expressed in the home country's currency, is defined as the difference between the firm's home-market price and the price it receives in its export market (net of tariff) multiplied by the exchange rate. According to (4) and (5a), the dumping margin, *DM*, can be expressed as:

$$DM = p_{1d}^* - \left(p_{1f}^* - \tau \right) R = B_1 - B_2 R,\text{[7]}$$

(11)

where $B_1 = \dfrac{a_d}{2}$ and $B_2 = \dfrac{a_f(2+b) - (2-b^2)\tau}{4-b^2} > 0$.

If $DM > 0$, then Firm 1 is regarded as committing dumping.[8] It is obvious that if $R < B_1/B_2 = R_D^*$, then $DM > 0$. However, since Firm 1 faces an uncertain world, thus it may exit when the exchange rate level is low enough. Dumping activity might occur only when the firm still stays in the market - that is, when $R > R_E^*$. Therefore, Firm 1 dumps its product into the foreign market if $R_E^* < R < R_D^*$. We define the interval of exchange rates in which dumping occurrence, *DP*, as:

$$DP = R_D^* - R_E^*.\text{[9]}$$

(12)

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[7] It is worth noting that since exchange rate changes are usually perceived as cost shocks, no exchange rate pass-through occurs in our model due to the assumption of zero production cost.

[8] If the dumping margin is very small, the firm can be exempted from imposing an AD duty. We ignore this exception rule in the AD rule.

[9] We assume $R_D^* > R_E^*$, because there is no dumping occurrence if $R_D^* < R_E^*$.

A larger value of *DP* does not necessarily imply a higher probability of dumping occurrence, since *R* follows a geometric Brownian motion. The probability of dumping can be expressed as:

$$\Pr\left(R_E^* < R < R_D^*\right) = N\left(m_D\right) - N\left(m_E\right)$$
$$= f\left(R_E^*\left(\sigma,\mu,K_1,\tau,b\right),R_D^*\left(\tau,b\right),\sigma,\mu,\ln R_0\right), \tag{13}$$

where $m_D = \dfrac{\ln R_D^* - E\ln R}{\sigma\sqrt{T}}$ and $m_E = \dfrac{\ln R_E^* - E\ln R}{\sigma\sqrt{T}}$; $N(.)$ is a cumulative standard normal distribution.

According to (13), the probability of dumping will be influenced through two possible channels - namely, the threshold effect (*TE*) and distribution effect (*DE*). Here, *TE* is attributed to the changes in R_D^* or R_E^* whereas *DE* is attributed to the changes in the distribution of exchange rate. From (13), it is clear that all variables considered in this paper might affect the probability of dumping occurrence through *TE*. However, among those variables, only σ and μ might affect the probability of dumping occurrence through *DE* as well. The total effect of σ or μ can be decomposed as follows:

$$\frac{df\left(\cdot\right)}{d\sigma} = \underbrace{\frac{\partial f\left(\cdot\right)}{\partial R_E^*} \cdot \frac{\partial R_E^*}{\partial \sigma}}_{TE_\sigma} + \underbrace{\frac{\partial f\left(\cdot\right)}{\partial \sigma}}_{DE_\sigma}, \tag{14a}$$

and

$$\frac{df\left(\cdot\right)}{d\mu} = \underbrace{\frac{\partial f\left(\cdot\right)}{\partial R_E^*} \cdot \frac{\partial R_E^*}{\partial \mu}}_{TE_\mu} + \underbrace{\frac{\partial f\left(\cdot\right)}{\partial \mu}}_{DE_\mu}. \tag{14b}$$

Lemma 1 The distribution effect of σ is positive if $\bar{R}_D^* > \bar{R}_E^* > \bar{R} + \sigma\sqrt{T}\omega_H$ or $\bar{R} + \sigma\sqrt{T}\omega_L > \bar{R}_D^* > \bar{R}_E^*$, whereas this effect is negative if $\bar{R} + \sigma\sqrt{T}\omega_H > \bar{R}_D^* > \bar{R}_E^* > \bar{R} + \sigma\sqrt{T}\omega_L$,

where $\bar{R} = E \ln R$, $\bar{R}_D^* = \ln R_D^*$, $\bar{R}_E^* = \ln R_E^*$, $\omega_H = \frac{1}{2}(\sigma\sqrt{T} + \sqrt{4 + T\sigma^2}) > 0$, and

$\omega_L = \frac{1}{2}(\sigma\sqrt{T} - \sqrt{4 + T\sigma^2}) < 0$.

Proof. See Appendix 1.

Lemma 2 The distribution effect of μ is positive if $\bar{R}_D^* > \bar{R}_E^* > \bar{R}$, and negative if

$\bar{R} > \bar{R}_D^* > \bar{R}_E^*$.

Proof. See Appendix 1.

Proposition 1 Exchange rate volatility, σ, is positively related to the probability of dumping

occurrence if $\bar{R}_D^* > \bar{R}_E^* > \bar{R} + \sigma\sqrt{T}\omega_H$ or $\bar{R} + \sigma\sqrt{T}\omega_L > \bar{R}_D^* > \bar{R}_E^*$.

Proof. From (14a), the threshold effect of σ is:

$$\frac{\partial f(\cdot)}{\partial R_E^*} \cdot \frac{\partial R_E^*}{\partial \sigma} = \frac{e^{-\frac{1}{2}m_E^2}}{\sqrt{2\pi T}} \frac{1}{\sqrt{2\rho\sigma^2 + (\mu - 0.5\sigma^2)^2}} > 0 .$$

According to Lemma 1, $df(\cdot)/d\sigma > 0$ under these conditions. ∎

Note that the exchange rate volatility influences the probability of dumping occurrence

through its effect on the threshold of exit and the distribution of *R* simultaneously. The

economic intuition of *TE* is that the exit is like a put option whose value increases if the

underlying uncertainty increases. Hence, the exporting firm has more incentive to wait until it

gets extra information from the market as the uncertainty rises. Therefore, the exiting

threshold R_E^* will be lower as σ rises. In other words, the firm will keep exporting at a very

low exchange rate level if the exchange rate volatility is high enough, and thus the probability

of dumping occurrence will be higher.

The distribution effect of σ is ambiguous, as shown in Lemma 1. It depends on the logarithmic values of exiting threshold ($\bar{R}_E^*$) and dumping threshold ($\bar{R}_D^*$), and the expectation of logarithmic exchange rate ($\bar{R}$). If the level of $\bar{R}$ is low enough ($\bar{R}_D^* > \bar{R}_E^* > \bar{R} + \sigma\sqrt{T}\omega_H$), or high enough ($\bar{R} + \sigma\sqrt{T}\omega_L > \bar{R}_D^* > \bar{R}_E^*$), DE will be positive; otherwise, it will be negative. In other words, this proposition suggests that if $\bar{R}_E^*$ and $\bar{R}_D^*$ are close to $\bar{R}$, then the exchange rate volatility tends to reduce the probability of dumping occurrence. In contrast, if $\bar{R}_E^*$ and $\bar{R}_D^*$ are far away from $\bar{R}$, then the exchange rate volatility might increase the probability of dumping occurrence. Consequently, the effect of exchange rate volatility on dumping seems to be asymmetric.

The logic behind the above result is as follows: An increase in exchange rate volatility will increase the probability of extreme values in the exchange rate to occur and lower the probability of the exchange rate to be around its mean as well. Therefore, an increase in volatility will lower the probability of dumping occurrence when the interval of dumping occurrence is around the mean of the distribution of exchange rate, whereas it will increase the probability of dumping occurrence when the interval of dumping occurrence locates on either tail of the distribution of the exchange rate, which implies that it is far away from its mean.

Proposition 2 Exchange rate trend μ is positively related to the probability of dumping occurrence if $\bar{R}_D^* > \bar{R}_E^* > \bar{R}$.

Proof: From (14b), the threshold effect of μ is:

$$\frac{\partial f(\cdot)}{\partial R_E^*} \cdot \frac{\partial R_E^*}{\partial \mu} = \frac{e^{-\frac{1}{2}m_E^2}}{\sigma\sqrt{2\pi T}} \frac{-R_E^* \cdot \psi}{(1+\alpha)(\rho-\mu)\sqrt{2\rho\sigma^2 + (\mu-0.5\sigma^2)^2}} > 0 .$$

Here, $\psi = \rho - \mu - (1+\alpha)\sqrt{2\rho\sigma^2 + (\mu-0.5\sigma^2)^2} < 0$. [10] According to Lemma 2,

$df(\cdot)/d\mu > 0$ if $\bar{R}_D^* > \bar{R}_E^* > \bar{R}$. ∎

Similar to exchange rate volatility, exchange rate trend μ also affects the probability of

dumping occurrence through two channels: threshold effect and distribution effect. As for

the threshold effect, since μ represents the expected future exchange rate level, an increase in

μ will increase the expected profit flows. Hence, it lowers the incentive of exiting the foreign

market and lowers the exiting threshold, thus increasing the probability of dumping

occurrence.

As regards the distribution effect, it is ambiguous as Lemma 2 shows. However, it will

be positive if $\bar{R}_D^* > \bar{R}_E^* > \bar{R}$. Thus, the exchange rate trend might increase the probability of

dumping occurrence if the thresholds are greater than the expected exchange rate level $\bar{R}$. It

is because an increase in μ raises the mean of exchange rate in addition to increasing the

probability of the exchange rate level whose value is greater than its mean. Consequently, the

relationship between exchange rate trend and the probability of dumping occurrence is

positive if $\bar{R}_D^* > \bar{R}_E^* > \bar{R}$. Furthermore, Lemma 2 shows that the distribution effect of μ is

negative if $\bar{R} > \bar{R}_D^* > \bar{R}_E^*$. It indicates that an increase in μ might dampen the dumping activity

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[10] See Chen et al. (2006) for the proof of $\psi < 0$.

when the expected exchange rate is high enough. Therefore, there also exists asymmetry in the effect of exchange rate trend on dumping activity.

Proposition 3 The initial (current) level of the logarithmic exchange rate, $\ln R_0$, is positively related to the probability of dumping occurrence if $\overline{R}_D^* > \overline{R}_E^* > \overline{R}$ and is negatively related to the probability of dumping occurrence if $\overline{R} > \overline{R}_D^* > \overline{R}_E^*$.

Proof: Since $E \ln R = \ln R_0 + \mu t - 0.5\sigma^2 t$, thus differentiating (13) with respect to $\ln R_0$ yields:

$$\frac{\partial f(\cdot)}{\partial \ln R_0} = \frac{1}{\sigma\sqrt{2\pi T}} \left[e^{-\frac{1}{2}m_E^2} - 2e^{-\frac{1}{2}m_D^2} \right],$$

According to the proof of Lemma 2 in Appendix 1, $\partial f(\cdot)/\partial \ln R_0 > 0$ if $\overline{R}_D^* > \overline{R}_E^* > \overline{R}$ and $\partial f(\cdot)/\partial \ln R_0 < 0$ if $\overline{R} > \overline{R}_D^* > \overline{R}_E^*$. ∎

This proposition shows that an appreciation of foreign currency tends to increase the probability of dumping occurrence if the current exchange rate level is below the dumping region, but tends to lower it if the current exchange rate level is above the dumping region. Thus, there also exists asymmetry in the effect of exchange rate level on dumping activity.

Proposition 4 Exit costs, K_1, are positively related to the probability of dumping occurrence.

Proof: Differentiating (13) with respect to K_1 yields:

$$\frac{\partial f(\cdot)}{\partial K_1} = \frac{1}{\sigma\sqrt{2\pi T}} \frac{1}{\frac{F_1}{\rho} - K_1} e^{-\frac{1}{2}m_E^2} > 0. \blacksquare$$

The intuition of Proposition 4 is straightforward. Since an increase in exit costs lowers

the incentive of exiting, thus it will lower the exiting threshold and thereby increase the probability of dumping occurrence.

Proposition 5 Tariff rate τ is positively related to the probability of dumping occurrence if $e^{-\frac{1}{2}m_D^2} > 2e^{-\frac{1}{2}m_E^2}$.

Proof: Differentiating (13) with respect to τ yields:

$$\frac{\partial f(\cdot)}{\partial \tau} = \frac{1}{\sigma\sqrt{2\pi T}} \frac{2-b^2}{a_f(2+b)-(2-b^2)\tau}\left[e^{-\frac{1}{2}m_D^2} - 2e^{-\frac{1}{2}m_E^2}\right].$$

It is obvious that $\partial f(\cdot)/\partial \tau > 0$ if $e^{-\frac{1}{2}m_D^2} > 2e^{-\frac{1}{2}m_E^2}$. ∎

A tariff affects R_D^* and R_E^* simultaneously. The first can be referred to as a price effect while the second as the exit effect. On the one hand, although an increase in the tariff rate raises the price of the exporting firm, the pass-through of a tariff on the import price is less than one, as illustrated in (5a). Thus, an increase in the tariff rate raises the dumping margin and the probability of dumping occurrence as well. On the other hand, an increase in the tariff rate tends to lower the profit flows as (7) shows, and thus increases the incentive of exiting as well as lowers the chance of dumping occurrence. Consequently, the effect of the changes in the tariff rate on the probability of dumping occurrence is ambiguous. However, the price effect of the trade cost dominates its exit effect when $e^{-\frac{1}{2}m_D^2} > 2e^{-\frac{1}{2}m_E^2}$, and thus the tariff is positively related to the probability of dumping occurrence under this condition.

Proposition 6 Product substitutability b is inversely related to the probability of dumping

occurrence if $e^{-\frac{1}{2}m_D^2} > 2e^{-\frac{1}{2}m_E^2}$.

Proof: Differentiating (13) with respect to b yields:

$$\frac{\partial f(\cdot)}{\partial b} = \frac{1}{\sigma\sqrt{2\pi T}} \frac{a_f(2+b)^2 + 4b\tau}{B_2(4-b^2)^2}\left[-e^{-\frac{1}{2}m_D^2} + 2e^{-\frac{1}{2}m_E^2}\right].$$

It is obvious that $\partial f(\cdot)/\partial b < 0$ if $e^{-\frac{1}{2}m_D^2} > 2e^{-\frac{1}{2}m_E^2}$. ∎

Similar to a tariff rate, product substitutability also affects R_D^* and R_E^* simultaneously. Since the prices of the firms are strategic complements in the model, an increase in b raises the equilibrium export price, thus decreasing the dumping margin and the probability of dumping occurrence as well. At the same time, it increases the profitability of the exporting firm as (7) shows, and thus lowers the exiting threshold. Therefore, its total effect is ambiguous. Similar to the case of the tariff rate, the price effect of product substitutability dominates its exit effect when $e^{-\frac{1}{2}m_D^2} > 2e^{-\frac{1}{2}m_E^2}$, and thus product substitutability is inversely related to the probability of dumping occurrence under this condition.

To illustrate the asymmetry in the effects of exchange rate volatility as well as exchange rate trend on the probability of dumping occurrence, numerical simulations are also conducted in this section. We choose a base set of parameter values as follows: $a_d = 1$, $a_f = 1$, $b = 0.5$, $\tau = 0.05$, $\rho = 0.05$, $F = 0.5$, $K_1 = 6$, $R_0 = 1$, $t = 1$, $\mu = 0$, and $\sigma = 0.1$. To allow the firm to have a chance to exit the market, the values of these parameters chosen exclude the case in which the net profit flows are certainly positive in each period. In addition, they also ensure that the probability of dumping occurrence is positive.

The effects of exchange rate volatility on the probability of dumping occurrence under different parameter values are shown in Figures 1a and 1b. Figure 1a uses the baseline values and the values of two thresholds are $R_E^* = 0.3527$ and $R_D^* = 0.7772$. Figure 1b changes the values of a_d and F to be $a_d = 1.4$ and $F = 0.75$, and the values of two thresholds become $R_E^* = 0.7935$ and $R_D^* = 1.0881$. Since the mean of the exchange rate in our setting is $e^{E \ln R} = 0.9980$, it is obvious that the threshold values in Figure 1b are around the mean, but those in Figure 1a are far away from the mean. Figure 1a demonstrates that the relationship between exchange rate volatility and the probability of dumping occurrence is positive whereas Figure 1b illustrates that the relationship is negative. Hence, the simulation results are consistent with the prediction of our theory.

Regarding the exchange rate trend μ, Figure 2a reveals that an increase in μ tends to reduce the probability of dumping occurrence while Figure 2b indicates that it tends to raise the probability of dumping occurrence. Here, $\bar{R}_D^*$ and $\bar{R}_E^*$ are smaller than $\bar{R}$ in Figure 2a, and thus *DE* is negative. We can see that the positive *TE* is dominated by the negative *DE*. In contrast, in Figure 2b, $R_E^* = 1.0581$ and $R_D^* = 1.1658$, and its total effect is positive, because *DE* becomes positive. These results are also consistent with the prediction of our theory.

4. Empirical model and methodology

From our theoretical framework, it is clear that the relationship between the exchange rate and dumping occurrence is not determinate, depending on the expected level of the

exchange rate. In order to test the validity of theoretical results, the level of the exchange rates of the importing country is first divided into two areas: one is a strong currency area (SCA), and the other is a weak currency area (WCA). In the SCA the level of the exchange rate is unusually high, and thus there is a high probability in which the exchange rate level is larger than the dumping threshold. In contrast, In the WCA the level of the exchange rate is unusually low, and thus there is a high probability that the exchange rate level is less than the exiting threshold. Therefore, our theoretical results imply that the exchange rate level and its trend tend to have a positive impact on dumping if the exchange rate level is in the WCA and a negative impact if the exchange rate level is in the SCA .

It has been similarly shown that exchange rate volatility tends to be positively related to the probability of dumping occurrence if the exchange rate level is high or low enough. Otherwise, exchange rate volatility and the probability of dumping occurrence might be inversely related. To test this result, we will divide the level of exchange rate into three regions: high, medium, and low.

Based on our theoretical results, the following empirical model is specified:

$$DUMP_t = \beta_0 + \beta_1 GDP_{t-1} + \beta_2 \log(R_{t-1}) + \beta_3 \mu_t + \beta_4 \sigma_t$$
$$+ \beta_5 \log(R_{t-1}) \times D_1 + \beta_6 \mu_t \times D_1 + \beta_{5+i} \sigma_t \times D_i + \varepsilon_t , \ i = 2, 3. \qquad (15)$$

Here, subscript t refers to time, β_j $(j = 0,1,...,8)$ are parameters, and ε_t's are disturbance terms. The definitions of the variables in (15) and the expected signs of the explanatory variables (summarized in Table 1) are explained as follows:

$DUMP_t$: the number of dumping filings.

GDP_{t-1} : the 3-year average rate of real GDP growth rate from time t-3 to t-1, whose expected sign is negative. The rationale is as follows: If the importing country, the United States, experiences an expansion, then an exporter would likely raise its export price, therefore reducing the likelihood of dumping. In a recession, in contrast, the exporter would likely reduce its price in the host market to retain market share, thus increasing the likelihood of dumping.[11]

R_{t-1} : the one-period lagged real effective exchange rate of the United States. The expected sign of this variable is ambiguous, depending on the level of exchange rates. According to our theory, the expected sign is positive in WCA and negative in SCA

μ_t, σ_t : the trend and volatility of the real effective exchange rate, respectively. The expected signs of these variables are ambiguous, also depending on the level of exchange rates. According to our theory the expected sign of exchange rate trend is positive in WCA and ambiguous in SCA. Moreover, the expected sign of exchange rate volatility is positive when the exchange rate level is high or low enough, otherwise, it is ambiguous. To measure the trend and volatility of the real effective exchange rate, μ_t and σ_t are defined respectively as a modified average and a modified standard deviation of the monthly changes in the log of the real effect exchange rate over the past 24 months; that is:

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[11] See Feinberg (2005: 613-614).

$$\sigma_t = \frac{1}{\sqrt{\Delta}} \left[\frac{1}{T-1} \sum_{j=1}^{T} \left(r_{t-j+1} - \frac{1}{T} \sum_{j=1}^{T} r_{t-j+1} \right)^2 \right]^{\frac{1}{2}} \quad , \quad \mu_t = \frac{1}{T \cdot \Delta} \sum_{j=1}^{T} r_{t-j+1} + \frac{\sigma_t^2}{2},$$

where $r_j = \log R_j - \log R_{j-1}$; $T = 24$; Δ is the space time interval, equal to $1/T$.[12]

D_1 : a dummy variable, whose value is 1 for the strong U.S. dollar period, 1980-1987,

and 0 for the weak U.S. dollar period, 1988-2005.

D_2, D_3 : dummy variables to denote unusually high or low exchange rate regions. The value

of D_2 is 1 if the real effective exchange rate is one standard error above its mean; and

0, otherwise. In contrast, the value of D_3 is 1 if the real effective exchange rate is one

standard error below its mean; and 0, otherwise.

Since the number of filings is a non-negative count number, following the previous

studies, our empirical model will be estimated with negative binomial regression.

5. The data and empirical results

5.1 The data

Since the United States is one of most active countries in adopting an AD policy, the

annual number of antidumping filing in the United States over 1980-2005 is used in this paper.

The AD procedure is composed of three stages: initiation, investigation, and decision. We

focus on the determinants of the AD initiations. As for the sources of the data, the initiation

cases are collected from the website of the World Trade Organization The real effective

exchange rate and real GDP growth rate of the United States are compiled from the database

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[12] See Tsay (2002: 229).

of the International Monetary Fund.

Table 2 presents the summary statistics of these variables. It shows that the number of AD filings fluctuated substantially during the sample period. In addition, the definitions of strong and weak currency areas seem reasonable, because the average of real effective exchange rate is 123.2 over 1979-1986 and 92.4 in the weak currency area. Finally, according to the definitions of D_2 and D_3, we have four years for D_2 and five years for D_3.

5.2 Empirical results

Table 3 reports our estimation results. The estimation in Column 1 does not consider the asymmetric effects of exchange rate variables on the dumping occurrence. The estimates of all coefficients in this case are not statistically significant. However, after controlling for the asymmetric effects as shown in other models in Columns 2-6 of Table 3, most coefficients are statistically significant. It indicates that it is essential to take into account asymmetric effects when analyzing the relationship between exchange rate movements and dumping activities.

The estimation in Column 2 tries to identify the differences in the effects of exchange rate level and its trend between strong currency and weak currency areas. It is shown that the antidumping filing is positively related to the exchange rate level, which suggests that the appreciation of the importing country tends to produce more dumping activities. This finding is consistent with most previous studies and our theory as well. Moreover, the interactive terms of exchange rate and D_1 have negative coefficients, which imply that, compared with the strong currency area, the appreciation of the importing country is more likely to stimulate

the antidumping activities in the weak currency area. However, the total effect is still positive ($\beta_2 + \beta_5 > 0$).

Regarding the exchange rate trend, the results are similar to the exchange rate level, but its total effects in the strong currency area become negative ($\beta_3 + \beta_6 < 0$). This result sheds light on the asymmetric effects demonstrated in our theoretical analysis. In other words, an expected appreciation of an importing country's currency will stimulate the dumping filings if the exchange rate level is low enough, while it will deter the dumping activities if its level is high enough.

Finally, the estimation in Columns 3-5 tries to identify the asymmetric effect of the volatility of exchange rate on dumping activities. Two dummy variables are used here: D_2 and D_3 represent that the exchange rate levels are very high and very low, respectively. All of the estimation results are positive, which suggest that an increase in exchange rate uncertainty tends to stimulate dumping activities. In addition, when the level of exchange rate is unusually high or unusually low, the magnitude of the estimated coefficients ($\beta_7, \beta_8, \beta_9$) are more significant and larger, which is also consistent with the prediction of our theoretical framework. The rationale behind this phenomenon is similar to the cost dumping case investigated in Dixit (1989). The more volatile the exchange rate is, the lower the willingness of exit will be. As a result, the probability of dumping occurrence increases. It is worth noting that the findings in this paper indicate that the increase in exchange rate volatility might result in more dumping occurrence when the level of exchange rate is unusually high or low.

6. Conclusions

This paper theoretically and empirically examines how exchange rate movements influence dumping occurrence. A real options model is used. Our results reveal that the effects of exchange rate level, its trend, and its volatility on the probability of dumping occurrence is ambiguous and asymmetric, depending on the level of exchange rate. An appreciation of the importing country's currency tends to have a positive impact on the probability of dumping occurrence if the exchange rate level is not too high. However, if the exchange rate level is unusually high, this positive relationship might lessen or even reverse. By contrast, exchange rate volatility tends to be positively related to the probability of dumping occurrence, if the exchange rate level is high or low enough. Otherwise, this positive relationship might weaken.

The number of antidumping cases filed from 1980 to 2005 by U.S. firms is employed to test the validity of our theoretical results. We find that an expected appreciation of the U.S. dollar tends to deter the AD filings in the strong dollar area while it stimulates the AD filings in the weak dollar area. Furthermore, the relationship between exchange rate volatility and AD filings is positive, especially in the time interval when the real effective exchange rate is high enough (one standard error above its mean) or low enough (one standard error below its mean). In short, the exchange rate movements have a significant effect on AD filings and these effects might be asymmetric. These results suggest that it is essential to take into

account the possible asymmetry in investigating the relationship between exchange rate

movements and dumping activities.

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Appendix 1 Proofs of Lemmas

Proof of Lemma 1

From (13) and (14a), we have:

$$DE_\sigma = \frac{1}{\sigma\sqrt{2\pi}}\left[e^{-\frac{1}{2}m_D^2}\left(\sigma\sqrt{T}-m_D\right)-e^{-\frac{1}{2}m_E^2}\left(\sigma\sqrt{T}-m_E\right)\right]$$

$$= \frac{1}{\sigma\sqrt{2\pi}}\left[H(m_D)-H(m_E)\right],\tag{A-1}$$

where $H(x)=e^{-\frac{1}{2}x^2}(\sigma\sqrt{T}-x)$. Since $R_D^* > R_E^*$, $m_D > m_E$. Thus, the sign of DE_σ is

positive (negative) if $H(x)$ is a monotonously increasing (decreasing) function of x.

Differentiating $H(x)$ with respect to x yields:

$$\frac{\partial H(x)}{\partial x}=e^{-\frac{1}{2}x^2}\left[x\left(x-\sigma\sqrt{T}\right)-1\right].$$

It is obvious that $H(x)$ is not a monotone function. However, $\partial H(x)/\partial x > 0$ if $x >$

$\frac{1}{2}(\sigma\sqrt{T}+\sqrt{4+T\sigma^2})$ or $x < \frac{1}{2}(\sigma\sqrt{T}-\sqrt{4+T\sigma^2})$. Therefore, DE_σ is positive if $m_D > m_E$

$> \omega_H$ or $m_E < m_D < \omega_L$ - that is, $\ln R_D^* > \ln R_E^* > E\ln R+\sigma\sqrt{T}\omega_H$ or, $E\ln R+\sigma\sqrt{T}\omega_L >$

$\ln R_D^* > \ln R_E^*$, where $\omega_H = \frac{1}{2}(\sigma\sqrt{T}+\sqrt{4+T\sigma^2})>0$ and $\omega_L = \frac{1}{2}(\sigma\sqrt{T}-\sqrt{4+T\sigma^2})<0$. ∎

Proof of Lemma 2

From (13) and (14b), we have:

$$DE_\mu = \frac{\sqrt{T}}{\sigma\sqrt{2\pi}}\left[e^{-\frac{1}{2}m_E^2}-e^{-\frac{1}{2}m_D^2}\right]$$

$$= \frac{\sqrt{T}}{\sigma\sqrt{2\pi}}\left[G(m_E)-G(m_D)\right],\tag{A-2}$$

where $G(x)=e^{-\frac{1}{2}x^2}$. Since $R_D^* > R_E^*$, $m_D > m_E$. Thus, the sign of DE_μ is positive (negative)

if $G(x)$ is a monotonously decreasing (increasing) function of x. Differentiating $G(x)$ with respect to x yields:

$$\frac{\partial G(x)}{\partial x} = -xe^{-\frac{1}{2}x^2}.$$

It is obvious that $G(x)$ is not a monotone function. However, $\partial G(x)/\partial x > 0$ if $x < 0$. Therefore, DE_μ is positive if $m_D > m_E > 0$ (or $\ln R_D^* > \ln R_E^* > E \ln R$) and negative if $m_E < m_D < 0$ (or $E \ln R > \ln R_D^* > \ln R_E^*$). ∎
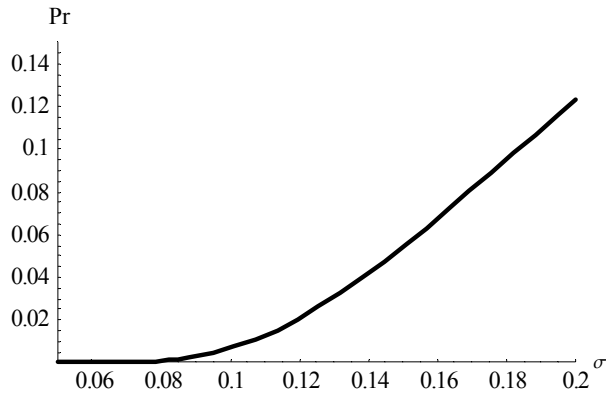
Figure 1a.   Exchange rate volatility and the probability of dumping occurrence:
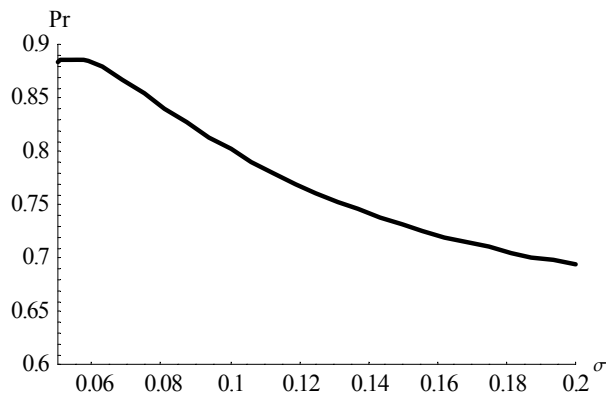
$a_d = 1; F = 0.5$

Figure 1b.   Exchange rate volatility and the probability of dumping occurrence:
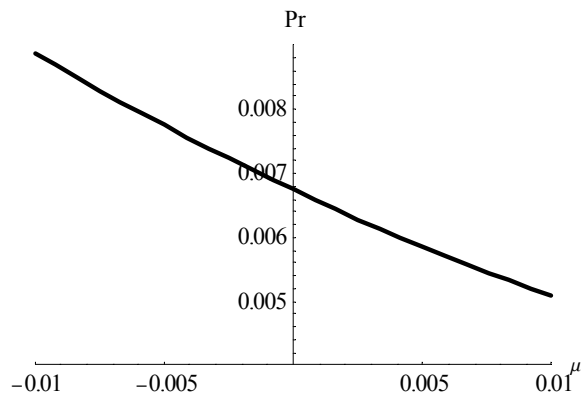
$a_d = 1.4; F = 0.75$

Figure 2a.   Exchange rate trend and the probability of dumping occurrence:
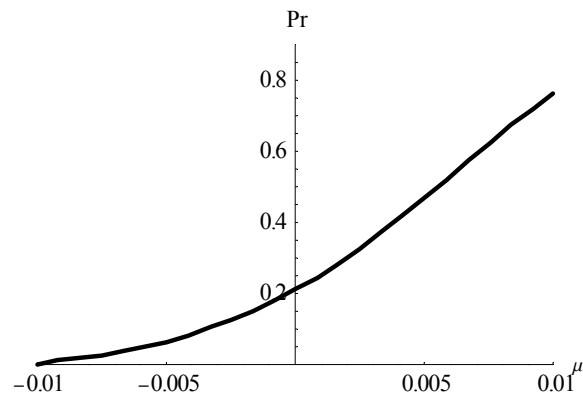
$a_d = 1; F = 0.5$

Figure 2b.   Exchange rate trend and the probability of dumping:
$a_d = 1.5$; $F = 0.9$

Table 1.   Expected Signs of The Exchange Rate Variables

	Exchange rate level (R)	Exchange rate trend (μ)	Exchange rate volatility (σ)
$\bar{R}_D^* > \bar{R}_E^* > \bar{R} + \sigma\sqrt{T}\omega_H$	+	+	+
$\bar{R}_D^* > \bar{R}_E^* > \bar{R}$	+	+	?
$\bar{R}_D^* > \bar{R} > \bar{R}_E^*$	?	?	?
$\bar{R} > \bar{R}_D^* > \bar{R}_E^*$	-	?	?
$\bar{R} + \sigma\sqrt{T}\omega_L > \bar{R}_D^* > \bar{R}_E^*$	-	?	+

Table 2.   Summary Statistics

Variables	Mean	Min	Max	Standard deviation
The number of AD initiation	39.3	12.0	84.0	21.5
Real effective exchange rate	101.6	80.1	143.2	17.4
Strong currency area (1979-1986)	123.2	103.7	143.2	14.5
Weak currency area (1987-2005)	92.4	80.6	106.6	7.3
GDP growth rate (%)	3.0	-1.9	7.2	1.8

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Table 3. Regression Results of The Determinants of Dumping Activity

Dependent Variable: The Number of AD Initiations

Explanatory Variables	(1) Coefficients	(2) Coefficients	(3) Coefficients	(4) Coefficients	(5) Coefficients
Intercept(β_0)	0.8343 (0.26)	-11.218[b] (-2.37)	-9.8687[b] (-2.51)	-15.907[a] (-3.28)	-13.277[a] (-3.54)
$GDP_{t-1}(\beta_1)$	-0.0168 (-0.17)	-0.0925 (-1.19)	-0.0625 (-0.71)	-0.0392 (-0.58)	-0.0086 (-0.11)
$\log(R_{t-1})(\beta_2)$	0.4308 (0.57)	3.0526[a] (3.63)	2.7510[a] (3.21)	4.0445[a] (3.77)	3.4681[a] (4.31)
$\mu_t(\beta_3)$	0.6865 (0.35)	5.2370[a] (2.65)	4.9204[b] (2.38)	5.3410[a] (2.64)	4.8807[b] (2.51)
$\sigma_t(\beta_4)$	24.113 (1.02)	39.467[b] (2.28)	37.048[c] (1.94)	36.953[a] (2.74)	33.980[b] (2.01)
$D_1 \times \log(R_{t-1})(\beta_5)$		-0.2655[a] (-5.09)	-0.2767[a] (-5.44)	-0.2963[a] (-5.69)	-0.3051[a] (-6.05)
$D_1 \times \mu_t(\beta_6)$		-6.3026[b] (-2.50)	-7.23[a] (-2.82)	-5.3634[b] (-2.34)	-6.7329[a] (-2.74)
$D_2 \times \sigma_t(\beta_7)$			7.9423 (0.91)		
$D_3 \times \sigma_t(\beta_8)$				12.885[c] (1.72)	
$(D_2 + D_3) \times \sigma_t(\beta_9)$					10.595[b] (1.99)
$\beta_2 + \beta_5$		2.7871[a] (3.46)	2.4743[a] (2.98)	3.7482[a] (3.63)	3.1627[a] (4.13)
$\beta_3 + \beta_6$		-1.0656 (-0.68)	-2.3110 (-1.08)	-0.0224 (-0.01)	-1.8521 (-1.08)
$\beta_4 + \beta_7$			44.991[b] (2.45)		
$\beta_4 + \beta_8$				49.838[a] (4.57)	
$\beta_4 + \beta_9$					44.575[b] (3.08)
Likelihood ratio test	204.21[a]	216.53[a]	217.02[a]	219.49[a]	219.68[a]

Notes: The z-statistics are in parentheses; superscripts a, b, and c denote that the test statistics are significant at the 1%, 5%, and 10% levels, respectively.