Exchange Rate Volatility and the Timing of Foreign Direct Investment: Market-seeking versus Export-substituting

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Abstract

This paper examines the impact of exchange rate uncertainty on the timing of foreign direct investment (FDI) with heterogeneous investing motives. We first extend Dixit-Pindyck's real options model to show that while an increase in exchange rate volatility tends to delay the FDI activity of a market-seeking firm, it might accelerate the FDI activity of an export-substituting firm if the firm's degree of risk aversion is high enough. The rationale behind this finding is that a market-seeking FDI might increase the exposure of the firm's profits to exchange rate risk, while an export-substituting FDI might reduce it. Firm-level data on the entry by Taiwanese firms into China over the period between 1987 and 2002 are used to test the theory's validity. Empirical evidence from a survival analysis based on the data is consistent with the theory. These results reveal that the relationship between exchange rate uncertainty and FDI is crucially dependent on the motives of the investing firms. Hence, it is essential to consider this factor in an empirical model so that the testing results are free from aggregation bias.

Keywords: FDI, exchange rate, real options, survival analysis

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1. Introduction

Ever since the breakdown of the Bretton Woods system in the 1970s, the exchange rates of many countries have been fluctuating considerably over time. A large body of recent research deals with the implications of exchange rate uncertainty for the real economy. Regarding the effects of exchange rate uncertainty on foreign direct investment (FDI, hereafter), while many theoretical and empirical studies indicate that exchange rate volatility has had a significant effect on FDI movements, the impact of exchange rates is found to be heterogeneous across countries and types of investment, and vary over time. [1]

Previous theoretical studies demonstrate that exchange rate volatility affects FDI activity through two main channels: firms' attitude towards risk and the option value of investment flexibility. It has been suggested that, for a risk-averse firm, higher volatility lowers the certainty equivalent value of the investing firm.[2] Hence, FDI decreases as exchange rate volatility increases. By contrast, Itagaki (1981), Cushman (1985), and Goldberg and Kolstad (1995) illustrate the importance of considering the post-FDI changes in the exposure of a firm's profits to exchange rate risk. If the investing firm can choose to serve foreign markets via exports or FDI, then an increase in exchange rate volatility might lead the firm to substitute FDI for exports, since FDI activity reduces the exposure of its profits to exchange rate risk.

The studies mentioned above are based on the traditional investment theory which assumes that an investment decision is to be taken now or never. They ignore the option of delaying an investment. Beginning in the 1980s a real options theory has been developed to analyze investment behavior. Under the assumptions of uncertainty and irreversible

[1] For instance, Amuedo-Dorantes and Pozo (2001), Bell and Campa (1997), Campa (1993, 1994), Darby et al. (1999), Crowley and Lee (2002), and Kiyota and Urata (2004) and Chen et al. (2005) find that exchange rate uncertainty deters FDI activity. However, Cushman (1985), Goldberg and Kolstad (1995), and Pain and Van Welsum (2003) illustrate that exchange rate stimulates FDI flows.

[2] See, for instance, Wihlborg (1978).

investment, the real options theory emphasizes the option value of the flexibility that a firm has in possibly delaying an investment decision in order to obtain more information about the future. Dixit (1989a,b) indicates that the waiting value increases as the uncertainty rises even for a risk-neutral firm. Hence, an increase in exchange rate uncertainty will defer the FDI activity of the firm. Using Dixit-Pindyck's (1994) model, however, Darby et al. (1999) illustrate that, for a risk-averse firm, the impact of exchange rate uncertainty on the timing of FDI is ambiguous.

A limitation of Dixit-Pindyck (1994) and Darby et al. (1999) is their treatment of firms' risk aversion. The risk aversion is incorporated into their model through a risk premium added to the private discount rate. This approach ignores an important feature in the traditional theory that allows the exposure of the investing firm's profits to exchange rate risk to vary with different types of FDI.[3] To fill the gap in the literature, the purpose of this paper is to reexamine the relationship between exchange rate uncertainty and FDI both theoretically and empirically.

We first develop an integrated framework of FDI under uncertainty in which a firm's attitude towards risk and the option value of investment flexibility are incorporated simultaneously. In this regard, Dixit-Pindyck's (1994) real options model is extended to consider possible changes in the post-FDI exposure to exchange rate risk. It is shown that the relationship between exchange rate uncertainty and FDI varies with the extent of the exposure to exchange rate risk which is determined by investing motives. This paper finds that exchange rate volatility tends to delay the FDI activity of a market-seeking firm, but it may accelerate the FDI activity of an export-substituting firm. We use firm-level data on Taiwan's outbound FDI in China over the period 1987-2002 to test the validity of our theoretical results.

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[3] Although Erdal (2001) and Chen et al. (2005) consider different motives of firms, the risk neutrality assumption in their model makes their results same as Dixit's analysis. The "exposure problem" also has not been discussed in their framework.

Empirical evidence from a survival analysis based on the data is consistent with the theory.

The remainder of the paper proceeds as follows. In the following section, Dixit-Pindyck's (1994) real options model is extended and the effects of exchange rate volatility on the FDI activity of market-seeking firms versus export-substituting firms are illustrated. Section 3 discusses our empirical methodology and model, followed in the subsequent section by a presentation of the data and empirical results. Brief concluding remarks are given in the final section.

2. A simple model of FDI under exchange rate uncertainty

Dixit-Pindyck's (1994) real options model is extended here to reexamine the relationship between exchange rate uncertainty and FDI. To illustrate the importance of the diversity of motives in investigating the determinants of the timing of FDI, we focus on two extreme cases according to motives of investing firms, namely, export-substituting FDI and market-seeking FDI. Export-substituting FDI refers to the situation in which an exporting firm, originally producing at its home country and serving a foreign market via exports, relocates its *whole* production abroad to serve the foreign market.[4] The motive for export-substituting FDI is to reduce the firm's production costs. By contrast, market-seeking FDI refers to the situation in which a domestic firm, originally not serving a foreign market via exports, chooses to set up a foreign subsidiary to produce and sell in a given foreign market. Thus, the motive of market-seeking FDI is to create a new market for its product.

Suppose that the firm is a price taker and it produces a unit flow of output at fixed marginal cost per period. For simplicity, we assume that the variable costs comprise labor cost only and the input-output coefficients are fixed to be one. Therefore, the variable costs can be treated as the wage rate. Finally, it is assumed the exchange rate R, expressed in units of home

[4] The conclusion remains the same even if we allow the firm to substitutes FDI for exports partially.

currency per foreign currency, follows an exogenously geometric Brownian motion

$$\frac{dR}{R} = \mu \cdot dt + \sigma \cdot dz \,. \tag{1}$$

Here, 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.[5]

The objective of the firm is assumed to obtain maximum expected utility in terms of its home country's currency. In order to introduce the concept of risk aversion and associate it with the motives of the firm, the following mean-variance expected utility function[6] is adopted:

$$EU(\pi) = E[\pi] - \frac{1}{2} a_p \mathrm{Var}(\pi) \tag{2}$$

where EU (.) is the expected utility; π shows profits of the firm; a_p is Arrow-Pratt's absolute risk aversion coefficient; Var(.) is the variance. Note that $\mathrm{Var}(\pi) = f(.)R_0^2 e^{2\mu t}(e^{\sigma^2 t} - 1)$, where R_0 is initial value of exchange rate and f(.)>0 is a function of π. It is obvious that a rise in σ or μ will increase the variance of the profits.

Export-substituting FDI

In the case of export-substituting FDI, it is assumed that there are two possible entry modes for the domestic firm to serve a foreign country: Export versus FDI. Suppose that prior to implementing FDI, a firm produces goods at its home country and exports products to a foreign country. Hence, its profit flows in terms of home country's currency per period are

$$\pi^0 = P_f R - W_d \tag{3a}$$

where π is the profit function; the superscript 0 represents the pre-FDI state; P_f is foreign market price in terms of foreign currency and W_d is domestic wage rate. After the firm invests

[5] The subscript t of R and π is suppressed in this section for simplicity.
[6] This functional form is used by Kawai (1984) and Qin (2000). Moreover, Cushman (1985) and Goldberg and Kolstad (1995) also use a similar setting to analyze the impact of exchange rate uncertainty on FDI.

to produce abroad and serve the foreign country from its foreign subsidiary[7], its profit flows become

$$\pi^1 = P_f R - W_f R \tag{3b}$$

where superscript 1 represents the post-FDI state; W_f is foreign wage rate in terms of foreign currency. From Equations (3a) and (3b), it is obvious that if the firm substitutes FDI for exports, the exposure of its profits to exchange rate risk will be reduced due to the fact that $(P_f R - W_f R) < P_f R$.

From Equations (1)-(3), the change in expected utility, $\Delta EU(\pi)$, from substituting FDI for exports can be derived as follows:

$$\Delta EU(\pi) = EU(\pi^1) - EU(\pi^0) = W_d - W_f E[R] - a\left[\left(P_f - W_f\right)^2 - P_f^2\right] e^{2\mu t}\left(e^{\sigma^2 t} - 1\right) \tag{4}$$

where $a = \frac{1}{2} a_p R_0^2$. From Equation (4), if the firm invests to produce at the foreign country and stays in the market forever, the change in expected present utility, ξ_E, becomes

$$\xi_E(R) = \int_0^\infty \Delta EU(\pi) e^{-\rho t} dt = -\frac{W_f R}{\rho - \mu} + \frac{W_d}{\rho} - a\left[\left(P_f - W_f\right)^2 - P_f^2\right]\gamma \tag{5}$$

where ρ is the firm's discount rate; $\gamma = \sigma^2 / [(\rho - 2\mu - \sigma^2)(\rho - 2\mu)]$; subscript E represents an export-substituting firm. For the purpose of convergence, we assume $\rho > 2\mu + \sigma^2$. It is obvious from Equation (5) that a depreciation of the home country's currency (i.e., an increase in R) causes a reduction in $\xi_E(R)$, thus deterring its firms' FDI activity.

The decision problem of the firm is to choose an optimal time to enter the foreign market. At time t, the firm can either produce in the host country after investing a lump sum k and gets the extra expected present utility as shown in Equation (5), or stays in the original state and keeps the right to invest in the next period. Hence, in each period the firm faces a binary

[7] We assume that the total output of the foreign subsidiary is sold in the foreign country. The reverse-import case is excluded in the model.

decision problem as follows:

$$V(R) = \max\left\{\xi_E(R) - k, \frac{1}{1+\Delta t \rho} E\left[V(R')|R\right]\right\} \tag{6}$$

where V is the optimal expected net present value; Δt is the time interval; k is the sunk costs expressed in the home country's currency; R' is the exchange rate in period t+1. The former term on the right-hand side, $\xi_E(R_t) - k$, is the net entry value, and the latter term, $(1+\Delta t \rho)^{-1} E[V(R') \mid R]$, is the value of the option to wait.

Since the utility function in this case is a decreasing function of R, there is a cutoff point, R_L, at which if $R<R_L$, then net entry value $\xi_E(R) - k$ is greater than the value of the option to wait. Thus, the firm's optimal decision is to carry out FDI. Using value-matching and smooth-pasting conditions, we have

$$R_L = \frac{\rho - \mu}{W_f} \frac{\alpha}{1+\alpha}\left[\frac{W_d}{\rho} + a\left[P_f^2 - \left(P_f - W_f\right)^2\right]\gamma - k\right] \tag{7}$$

where $\alpha = \sigma^{-2}[(\mu - 0.5\sigma^2) + \sqrt{(\mu - 0.5\sigma^2)^2 + 2\sigma^2 \rho}] > 0$.[8] The higher the value of R_L is, the higher the probability will be that R is smaller than R_L. Hence, the firm has higher incentive to invest earlier. To ensure that there is a possibility for a risk-neutral firm to undertake FDI, we assume that $W_d / \rho - k > 0$.

In the following, before we discuss the general case presented in Propositions 4 and 5, we first derive the results of two special cases which correspond to the specifications in previous studies. The first special case is an investment decision of a risk-averse firm that has to be taken now or never; that is, there is no option to delay the investment. The other special case is an investment decision of a risk-neutral firm with an option to delay the investment.

[8] See Dixit (1989b), p.626.

Proposition 1 In the case of export-substituting FDI, an increase in exchange rate volatility will stimulate FDI activity of a firm if the firm cannot delay its investment.

Proof: From Equation (5), it can be shown that

$$\frac{\partial \xi_E}{\partial \sigma} = a\left[P_f^2 - \left(P_f - W_f\right)^2\right]\frac{2\sigma}{(\rho - 2\mu - \sigma^2)^2} > 0,$$

which implies that the firm has a higher incentive to substitute FDI for exports if the exchange rate uncertainty rises. ■

The economic rationale behind Proposition 1 is straightforward. If the firm cannot delay its investment, then the risk attitude is the only channel through which exchange rate uncertainty affects FDI. Substituting FDI for exports reduces the firm's exposure to exchange rate risk, and this gain from risk reduction is larger if the exchange rate is more volatile. Consequently, an increase in exchange rate volatility stimulates the firm's FDI activity. This result is similar to that found in Itagaki (1981).

Proposition 2 **A** risk-neutral export-substituting firm will delay its FDI activity when the exchange rate volatility rises; that is, $\partial R_L / \partial \sigma |_{a_p=0} < 0$.

Proof: From Equation (7), we have

$$\left.\frac{\partial R_L}{\partial \sigma}\right|_{a_p=0} = \frac{R_L}{\alpha\left(1+\alpha\right)}\frac{\partial \alpha}{\partial \sigma} < 0$$

where $\frac{\partial \alpha}{\partial \sigma} = -\frac{\alpha}{\sigma}[1 + \frac{2\mu + \sigma^2}{2\sqrt{2\rho\sigma^2 + (\mu - 0.5\sigma^2)^2}}] < 0$.■

The economic intuition of Proposition 2 is as follows. If the firm is risk-neutral, then the option value of investment flexibility is the only channel through which exchange rate uncertainty affects FDI. An investment is like a call option whose value rises if the underlying uncertainty increases. Hence, facing an irreversible investment and uncertain future, a potential entrant has more incentive to delay its investment so as to get extra information.

Proposition 3 **A** risk-neutral export-substituting firm will delay its FDI activity under a rising exchange rate trend; that is, $\partial R_L / \partial \mu |_{a_p=0} < 0$.

Proof: From Equation (7), we have

$$\left.\frac{\partial R_L}{\partial \mu}\right|_{a_p=0} = \frac{R_L \cdot \psi}{(1+\alpha)(\rho-\mu)\sqrt{2\rho\sigma^2 + (\mu - 0.5\sigma^2)^2}} < 0.$$

where $\psi = \rho - \mu - (1+\alpha)\sqrt{2\rho\sigma^2 + (\mu - 0.5\sigma^2)^2} < 0$.[9]

The reason for μ to be negatively related to the FDI activity of a risk-neutral firm is due to the fact that μ represents the expected future level of exchange rate. Moreover, a greater level of μ implies that the probability of future level of exchange rate being less than R_L is smaller. Hence, the risk-neutral firm will delay its investment as μ rises.

Lemma 1 $\partial^2 R_L / \partial\sigma\partial a_p > 0$ and $\partial^2 R_L / \partial\mu\partial a_p > 0$.

Proof: See Appendix 1.

Proposition 4 In the case of export-substituting FDI, the effect of exchange rate volatility on the timing of FDI is ambiguous. However, there exists a threshold in the degree of risk aversion $\tilde{a}$ such that this effect is positive (negative) if the firm's risk-aversion coefficient a_p is greater (smaller) than $\tilde{a}$.

[9] See Chen et al. (2005, p.15) for the proof of $\psi < 0$.

Proof: From Equation (7), we have

$$\frac{\partial R_L}{\partial \sigma} = \Gamma_1 + a_p \Gamma_2 \tag{8a}$$

where

$$\Gamma_1 = \frac{\rho - \mu}{W_f} \frac{1}{(1+\alpha)^2} \left[\frac{W_d}{\rho} - k \right] \frac{\partial \alpha}{\partial \sigma}$$

and

$$\Gamma_2 = \frac{R_0^2}{2} \frac{\rho - \mu}{W_f} \frac{\alpha}{1+\alpha} \left[P_f^2 - \left(P_f - W_f \right)^2 \right] \left[\frac{\gamma}{\alpha(1+\alpha)} \frac{\partial \alpha}{\partial \sigma} + \frac{2\sigma}{(\rho - 2\mu - \sigma^2)^2} \right].$$

Given $\partial R_L / \partial \sigma |_{a_p = 0} = \Gamma_1 < 0$ (Proposition 2) and $\partial^2 R_L / \partial \sigma \partial a_p = \Gamma_2 > 0$ (Lemma 1), since $\partial R_L / \partial \sigma$ is a linear function of *a*, there must exist a critical value, $\tilde{a}$, at which $\partial R_L / \partial \sigma > 0$ if $a_p > \tilde{a}$, and $\partial R_L / \partial \sigma < 0$ if $a_p < \tilde{a}$. ■

The economic intuition of Proposition 4 is as follows. As shown in Propositions 1 and 2, exchange rate volatility σ affects the FDI through two channels: the risk attitude of a firm and the option value of investment flexibility. These two channels have opposite effects on the FDI activity of an export-substituting firm. Therefore, the effect of exchange rate volatility on FDI is ambiguous. However, given the negative effect on FDI activity from the option value of investment flexibility, if the positive effect resulting from the risk aversion as well as the change in the exposure to exchange risk resulting from the firm's FDI becomes large (small) enough, the net effect will be positive (negative).

Proposition 5 In the case of export-substituting FDI, the effect of the exchange rate trend on the timing of FDI is ambiguous. However, there exists a threshold in the degree of risk aversion $\hat{a}$ such that this effect is positive (negative) if the firm's risk-aversion coefficient a_p is greater (smaller) than $\hat{a}$.

Proof: From Equation (7), we have

$$\frac{\partial R_L}{\partial \mu} = \Upsilon_1 + a_p \Upsilon_2 \tag{8b}$$

where

$$\Upsilon_1 = \frac{\psi\alpha}{(1+\alpha)^2 W_f \sqrt{2\rho\sigma^2 + (\mu - 0.5\sigma^2)^2}} \left[\frac{W_d}{\rho} - k \right]$$

and

$$\Upsilon_2 = \frac{R_0^2}{2} \frac{(\rho-\mu)\alpha}{W_f(1+\alpha)} \left[P_f^2 - \left(P_f - W_f\right)^2 \right] \left[\frac{\psi\gamma}{(1+\alpha)(\rho-\mu)\sqrt{2\rho\sigma^2 + (\mu - 0.5\sigma^2)^2}} + \frac{\partial \gamma}{\partial \mu} \right]$$

and

$$\frac{\partial \gamma}{\partial \mu} = \frac{2\sigma^2(2\rho - 4\mu - \sigma^2)}{(\rho - 2\mu - \sigma^2)^2 (\rho - 2\mu)^2} > 0 .$$

Given $\partial R_L / \partial \mu |_{a_p=0} = \Upsilon_1 < 0$ (Proposition 3) and $\partial^2 R_L / \partial \mu \partial a_p = \Upsilon_2 > 0$ (Lemma 1), since $\partial R_L / \partial \mu$ is a linear function of *a*, there must exist a critical value, $\hat{a}$, at which $\partial R_L / \partial \mu > 0$ if $a_p > \hat{a}$, and $\partial R_L / \partial \mu < 0$ if $a_p < \hat{a}$. ■

Regarding the effect of exchange rate trend μ, on the one hand, because μ represents the expected future level of exchange rate, an increase in μ decreases the probability of future level of exchange rate being smaller than R_L. Hence, the firm will delay its investment, as shown in Proposition 3. On the other hand, an increase in μ will raise the variance of a firm's profits as mentioned above, and thus stimulate the FDI activity of a risk-averse export-substituting firm. Therefore, the effect of exchange rate trend on FDI is also ambiguous. However, the latter effect is larger for a higher risk-averse firm, as shown in Lemma 1. Thus, when the degree of risk aversion exceeds a critical level, the latter positive effect will dominate the former negative effect, meaning an increasing trend in exchange rate will stimulate FDI activity of an export-substituting firm, and vice versa.

Market-seeking FDI

Since we assume a market-seeking firm has not served the foreign market via exports prior to undertaking FDI, the profits from exports are zero in state 0. The change in net present utility, ξ_M, from FDI can be shown as follows[10]:

$$\xi_M(R) = \frac{(P_f - W_f)R}{\rho - \mu} - a(P_f - W_f)^2 \gamma \tag{9}$$

where subscript M represents the market-seeking firms. It is obvious from Equation (9) that a depreciation of the home country's currency (i.e., an increase in R) will raise the value of $\xi_M(R)$, thus stimulating its firms' FDI activity.

The binary decision problem for the firm in each period is

$$V(R) = \max\left\{\xi_M(R) - k, \frac{1}{1+\Delta t\rho} E\left[V(R')\middle|R\right]\right\} \tag{10}$$

There is an entry threshold rate R_H at which a potential entrant enters if $R>R_H$. In other words, the lower the value of R_H is, the higher the incentive will be for the firm to enter the market. Using value-matching and smooth-pasting conditions, we have

$$R_H = \frac{\rho - \mu}{P_f - W_f} \frac{\beta}{\beta - 1}\left[a(P_f - W_f)^2 \gamma + k\right] \tag{11}$$

where $\beta = \sigma^{-2}[-(\mu - 0.5\sigma^2) + \sqrt{(\mu - 0.5\sigma^2)^2 + 2\sigma^2\rho}] > 1$.[11]

Proposition 6 In the case of market-seeking FDI, an increase in exchange rate volatility will delay the FDI activity of the firm; that is, $\partial R_H / \partial \sigma > 0$.

Proof: From Equation (11), we have

[10] The derivation of this equation is similar to the case of the export-substituting FDI.
[11] See Dixit (1989b), p.626.

$$\frac{\partial R_H}{\partial \sigma}=\frac{-R_H}{\beta(\beta-1)}\frac{\partial \beta}{\partial \sigma}+\frac{\rho-\mu}{P_f-W_f}\frac{\beta a}{\beta-1}\left(P_f-W_f\right)^2\frac{2\sigma}{(\rho-2\mu-\sigma^2)^2}>0, \qquad (12a)$$

where $\frac{\partial \beta}{\partial \sigma}=\frac{\beta}{\sigma}[-1+\frac{2\mu+\sigma^2}{2\sqrt{2\rho\sigma^2+(\mu-0.5\sigma^2)^2}}]<0$, given the assumption $\rho>2\mu+\sigma^2$. ■

The economic intuition of Proposition 6 is as follows. In this case, FDI activity will make the firm's exposure to exchange rate risk increase. Thus, an increase in exchange rate volatility will reduce the expected utility gain from this activity for a risk-aversion firm. At the same time, an increase in exchange rate volatility will increase the option value of delaying the investment so as to deter the FDI activity further.

Proposition 7 A risk-neutral market-seeking firm will accelerate its FDI activity when the exchange rate trend rises, that is, $\partial R_H/\partial\mu|_{a_p=0}<0$.

Proof: From Equation (11), it can be shown that

$$\left.\frac{\partial R_H}{\partial \mu}\right|_{a_p=0}=\frac{R_H\cdot\phi}{(\beta-1)(\rho-\mu)\sqrt{2\rho\sigma^2+\left(\mu-0.5\sigma^2\right)^2}}<0$$

where $\phi=\rho-\mu-(\beta-1)\sqrt{2\rho\sigma^2+(\mu-0.5\sigma^2)^2}<0$.[12] ■

Similar to Proposition 3, the economic intuition of Proposition 7 is straightforward. An increase in μ raises the probability of future exchange rate level to be larger than R_H, and thus stimulates the risk-neutral firm to invest earlier.

Lemma 2 $\partial^2 R_H/\partial\mu\partial a_p>0$.

[12] See Chen et al. (2005, p.14) for the proof of $\phi<0$.

Proof: See Appendix 1.

Proposition 8 In the case of market-seeking FDI, the effect of exchange rate trend on the timing of FDI is ambiguous. However, there exists a threshold in the degree of risk aversion $\overline{a}$ such that this effect is negative (positive) if the firm's risk-aversion coefficient a_p is greater (smaller) than $\overline{a}$.

Proof: From Equation (11), we have

$$\frac{\partial R_H}{\partial \mu} = \Lambda_1 + \Lambda_2 a_p, \qquad (12b)$$

where

$$\Lambda_1 = \frac{\phi\beta k}{(\beta-1)^2(P_f - W_f)\sqrt{2\rho\sigma^2 + (\mu - 0.5\sigma^2)^2}}$$

and

$$\Lambda_2 = \frac{R_0^2}{2}\frac{\rho-\mu}{P_f - W_f}\frac{\beta}{\beta-1}\left(P_f - W_f\right)^2\left[\frac{\phi\gamma}{(\beta-1)(\rho-\mu)\sqrt{2\rho\sigma^2+(\mu-0.5\sigma^2)}} + \frac{\partial\gamma}{\partial\mu}\right]$$

Here $\partial R_H/\partial\mu$ is a linear function of *a*. In addition, $\partial R_H/\partial\mu\,|_{a_p=0} = \Lambda_1 < 0$ (Proposition 7) and $\partial^2 R_H/\partial\mu\partial a_p = \Lambda_2 > 0$ (Lemma 2), which must exist a trigger value $\overline{a}$ at which $\partial R_H/\partial\mu > (<) 0$ if $a_p > (<)\overline{a}$. ■

The reasoning regarding the effect of exchange rate trend in the market-seeking case is similar to what we have found in the export-substituting case. An increase in μ affects FDI through two channels: the probability of *R* being greater R_H and the variance of the firm's profits. The effect of an increase μ on FDI activity from the first channel is positive (Proposition 7), and the effect from the second channel is negative, its total effect is ambiguous. However, when the degree of risk aversion exceeds a trigger level, the second effect will dominate the first effect, thus an increasing trend in exchange rate will defer FDI activity of a market-seeking firm, and vice versa.

Proposition 9 Sunk costs are negatively related to the FDI activity of both export-substituting firms and market-seeking firms; that is, $\partial R_L / \partial k < 0$, and $\partial R_H / \partial k > 0$.

Proof: The proofs are straightforward, and thus are omitted.

The economic intuition of Proposition 9 is clear that the higher the entry costs are, the higher the revenues or the lower the variable costs will be that are requested to compensate for the opportunity loss.

Proposition 10 The FDI activity of export-substituting firms is negatively related to foreign wage rate and positively related to domestic wage rate; that is, $\partial R_L / \partial W_f < 0$, $\partial R_L / \partial W_d > 0$.

Proof: From Equation (7), it can be shown that

$$\frac{\partial R_L}{\partial W_d} = \frac{\rho - \mu}{W_f} \frac{\alpha}{1+\alpha} \frac{1}{\rho} > 0,$$

and

$$\frac{\partial R_L}{\partial W_f} = -\frac{\rho - \mu}{W_f^{\ 2}} \frac{\alpha}{1+\alpha} \left(\frac{W_d}{\rho} + aW_f^{\ 2} - k \right) < 0.$$

The second inequality holds due to the assumption of $W_d / \rho - k > 0$, mentioned in Equation (7).■

Proposition 11 The foreign wage rate is negatively related to the FDI activity of a risk-neutral market-seeking firm. However, the relationship between foreign wage rate and the FDI activity for a risk-averse market-seeking firm is ambiguous.

Proof: From Equation (11), we have

$$\frac{\partial R_H}{\partial W_f} = \frac{\rho - \mu}{(P_f - W_f)^2} \frac{\beta}{\beta - 1}\left[k - a(P_f - W_f)^2 \gamma\right].$$

It is obvious that the sign of $\partial R_H / \partial W_f$ is ambiguous, depending on the relative magnitude of risk aversion, a_p, and the sunk costs, k. However, if a_p =0, then $\partial R_H / \partial W_f > 0$. ■

An increase in domestic wage will make the variable production costs in the foreign country relatively cheap, and thus cause export-substituting FDI to increase. Therefore, the relation between domestic wage and export-substituting FDI is positive. As for the reason why the effect of foreign wage on the FDI activity of export-substituting firms is negative while its effect on the FDI activity of market-seeking is ambiguous is due to the following fact: on the one hand, the higher the foreign wage rate is, the higher the variable costs will be that are involved in foreign production which reduces the profitability of both types of FDI. On the other hand, an increase in the foreign wage rate will raise the exposure of the profits of an export-substituting FDI, but reduce the exposure of the profits of a market-seeking FDI. Therefore, the total effect of foreign wage rate on the FDI activity of export-substituting firms is negative, while its effect on the FDI activity of market-seeking is ambiguous. Nevertheless, as obvious from the proof of Proposition 11, if the sunk costs are high, or the degree of risk aversion is low enough, then the total effect of foreign wage rate on the FDI activity of market-seeking is also negative.

To sum up, we develop an integrated model of FDI under uncertainty to reexamine the relationship between exchange rate uncertainty and FDI activity with heterogeneous investing motives. We find that while exchange rate volatility tends to defer the FDI activity of a market-seeking firm, it may accelerate the FDI activity of an export-substituting firm if the degree of risk aversion is high enough. We have shown that previous studies with either a real options model (such as Dixit (1989a, b), or a traditional risk-aversion model (such as Itagaki (1981), Goldberg and Kolstad (1995) and Cushman (1985)), are equivalent to the special cases of our model. Our results demonstrate the importance in considering the diversity of investing motives when examining the relationship between exchange rate uncertainty and FDI activity. Table 1 summarizes the expected signs of the determinants of market-seeking FDI versus export-substituting FDI.

3. Empirical methodology and model

3.1 Empirical methodology

This paper focuses on the analysis of how exchange rate volatility affects the timing of foreign entry. One widely applied method to examine the issue about timing is to conduct event history analysis. Event history analysis investigates what may happen over a time span before a certain event occurs. In our case, the event is a firm's entry into a foreign market. The waiting time for a firm to enter a foreign market can be treated as the survival time of the firm, and the timing of entry can be treated as the timing of event occurrence.

To apply this method, one needs to specify a survival function to describe the probability of a firm's survival until a certain time has elapsed. The probability of a firm's entry at a certain time period can be expressed by a hazard function. When we denote the probability density function of event occurrence as $f(t)$, the hazard function $h(t)$ can be written as $h(t) = f(t)/S(t)$, where $S(t)$ is the survival function which can be specified as $S(t) = \Pr(T \geq t)$, where T is the duration of survival of a firm and t is a certain time point.

This paper adopts Cox's proportional hazard model (Cox (1972, 1975)).[13] One of the advantages about Cox's model is that it imposes the condition of "hazard proportionality" and thus makes the analysis of covariates possible without specifying a hazard function itself. The

[13] Cox model was originally developed in the field of biology and medical science. It has been applied in economics and other social sciences since the mid 1990s, such as the survival time of corporate firms (e.g. Kimura and Fujii (2003) and Van Kranenburg et al. (2002)), the entry time of firms (e.g. Kogut and Chang (1996), Ursacki and Vertinsky (1992), and Leung et al. (2003)), and problems in management (e.g. Fuentelsaz et al. (2002) and Tan et al. (2002)) or political science (e.g. Box Steffensmeier (1996) and Oneal and Russett (1997)).

model treats each sample's hazard rate $h_i(t)$ as a function of a number of covariates and conceptually defines the baseline hazard $h_0(t)$ that is not influenced by any covariate. Based on the hazard proportionality assumption, the model treats the proportion of $h_i(t)$ and $h_0(t)$ as constant. Hence, the proportion is interpreted as a function of covariates.[14]

We define the hazard rate as the rate at which a firm invests in a foreign country by *t* given that the firm has stayed in the home country until *t*. Thus, the hazard function, $h(t \mid \mathrm{x}_i)$, can be expressed as[15]

$$h\left(t \mid \mathrm{x}_{i1}, \mathrm{x}_{2i}(t)\right) = h_0\left(t\right)\exp\left(\beta'\mathrm{x}_{1i} + \alpha'\mathrm{x}_{2i}(t)\right) \tag{13}$$

where $h_0(t)$ is the baseline hazard function; β and α are $p \times 1$ and $q \times 1$ vectors, respectively; x_{1i} is a vector of time-independent covariates; $\mathrm{x}_{2i}(t)$ is a vector of time varying covariates; subscript *i* represents i[th] firm; subscript *t* represents time.

Suppose that we have a dataset with *n* observations and *K* distinct entry times. If we sort the sample by the order of entry times, then the partial likelihood function, L_p, becomes

$$L_p = \prod_{i=1}^{n}\left[\frac{e^{\beta'\mathrm{x}_{1i} + \alpha'\mathrm{x}_{2i}(t)}}{\sum_{j \in \Omega(t_i)} e^{\beta'\mathrm{x}_{1j} + \alpha'\mathrm{x}_{2j}(t)}}\right]^{\delta_i} \tag{14}$$

where $\Omega(t_i)$ represents the number of firms that are at risk of experiencing an entry at time t_i, that is, the "risk set"; δ_i is an indicator, its value is 0 if the sample is right-censored, and 1 if the sample is uncensored.[16] The positive (negative) estimators $\hat{\beta}$ and $\hat{\alpha}$ represent the variables have positive (negative) impacts on the occurrence of the event. To solve Equation

[14] See Box-Steffensmeier and Jones, (2004), Chapters 2 and 4.
[15] For more details, see Lawless (2003) or Box-Steffensmeier and Jones (2004).
[16] If firms do not invest in the sample period but may invest in the future, then the sample is referred to as a right-censored sample.

(14), there are three methods to compute the ties[17]: Breslow method, Efron method and Exact discrete method[18]. It turns out that our results are not sensitive to which method is used.

3.2 Empirical model

Based on the theoretical framework of this paper and Equation (13), the following empirical model is established:

$$\begin{aligned}\log\left[h(t)/h_0(t)\right] = {} & \alpha_1\sigma_t + \alpha_2 EX_M * \sigma_t + \alpha_3 EX_E * \sigma_t \\ & + \alpha_4 R_{t-1} + \alpha_5 EX_M * R_{t-1} + \alpha_6 EX_E * R_{t-1} \\ & + \alpha_7 \mu_t + \alpha_8 EX_M * \mu_t + \alpha_9 EX_E * \mu_t \\ & + \alpha_{10} WAGE_{t-1} + \alpha_{11} PF_{i,t_i} \\ & + \beta_1 MKT + \beta_2 FUND_i \\ & + \beta_3 R\&D_i + \beta_4 SIZE_i + \beta_5 SIZE_i * SIZE_i \\ & + \beta_6 KL_i + \beta_7 HT_i\end{aligned} \tag{15}$$

Here, subscript *i* represents i[th] firm and subscripts *M* and *E* represent the market-seeking firm and export-substituting firm, respectively. Since Taiwanese firms were not permitted to invest in China until 1987, the dependent variable is defined as the duration from 1987 to the year when the firm invested there. As for independent variables, in addition to the variables suggested in Section 2, some are added as explanatory variables in order to control for some important factors that are not considered in our theoretical framework. The definition of these variables and their expected signs are discussed as follows (see also Table 2):

σ_t : exchange rate volatility. According our model in Section 2, while exchange rate uncertainty tends to deter the FDI activity of market-seeking firms, its impact on export-substituting firms is ambiguous. To test the validity of our theory, we define two dummy variables: 1. EX_M , whose value is 1 for market-seeking firms, and 0 otherwise; 2. EX_E , whose value is 1 for export-substituting firms, and 0 otherwise. Therefore, the expected

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[17] "Ties" occur when two or more firms enter a market at the same observed time.

[18] See Box-Steffensmeier and Jones (2004) p.54。

sign of $(\alpha_1+\alpha_2)$ is negative, and that of $(\alpha_1+\alpha_3)$ is positive (negative) for those export-substituting firms with high (low) risk-aversion.

$R_{t\text{-}1}$: one-period lagged real exchange rate of NTD versus RMB, in which nominal exchange rates are deflated with prices of the respective countries to control for the possible movements in prices following the change in nominal exchange rates. Since it is time-consuming to make an FDI decision, the final decision might be more related to the previous exchange rate level, and thus the one-period lagged values are used. According to our model, an appreciation of the host country's currency increases market-seeking firms' profits in terms of the home currency and decreases those of export-substituting firms. In the empirical equation we also use the dummy variables EX_M and EX_E to test the validity of our theoretical results. The expected sign of $(\alpha_4+\alpha_5)$ is positive, and that of $(\alpha_4+\alpha_6)$ is negative.

μ_t : trend of exchange rate. According to our theoretical framework, for firms with very low risk-aversion, an increase in μ_t accelerate the FDI activity of market-seeking firms and delay the FDI activity of export-substituting firms. By contrast, for firms with very high risk-aversion, an increase in μ_t delays the FDI activity of market-seeking firms and accelerates the FDI activity of export-substituting firms. Therefore, if the risk- aversion of the firms is very low, then the expected sign of $(\alpha_7+\alpha_8)$ is positive and that of $(\alpha_7+\alpha_9)$ is negative. If the risk-aversion of the firms is very high, then the expected sign of $(\alpha_7+\alpha_8)$ is positive and that of $(\alpha_7+\alpha_9)$ is negative.

W_f/W_d : wage rate of the foreign country relative to that of the home country. The ratio of China's one-period lagged real wage rate over Taiwan's one-period lagged real wage rate ($WAGE_{t\text{-}1}$) is used. According to our theory, the expected sign of the coefficient for export-substituting firms is negative, and that for market-seeking firms is ambiguous.

MKT_i: marketing intensity, a proxy variable of the sunk costs. According our theory, the expected sign of its coefficient is negative.

As for the control variables, based on the previous studies,[19] the following variables are used: profits (*PF*), source of funds (*FUND*), R&D intensity (*R&D*), firm's size (*SIZE*), capital-labor ratio (*KL*), and high-tech industry dummy (*HT*). According to the liquidity hypothesis, since the cost of internal funds is viewed by investors to be lower than the costs of external funds,[20] there is a positive relation between a firm's internal cash flows and its investment abroad. The profit rate ($PF_{i,t}$) is used as a proxy of a firm's internal capital, the expected sign of its coefficient is positive. In addition, if the parent company of an investing firm can provide necessary funds, it suggests that the firm is more unlikely to face financial constrain, and thus it will be more likely to enter foreign markets earlier. We create a dummy variable $FUND_i$, whose value is 1 if the parent company provides the necessary funds and 0 otherwise. We expect the sign of its coefficient to be positive.

The internalization hypothesis indicates that due to high transaction costs of intangible assets, an investing firm with superior knowledge and management expertise will choose to set up a subsidiary rather than simply licensing a foreign firm to produce the product. R&D intensity variable ($R\&D_i$) is used as a measure of the investing firm's intangible asset. The expected sign of this variable is positive.[21] In addition, Horst (1972) argues that a firm's success at home will be highly correlated with its success abroad, since both are the result of the same technological and marketing capabilities. Hence, lager firms are more likely to invest abroad than smaller firms. The sales of a firm ($SIZE_i$) are used to measure its size and its expected sign is positive. However, as pointed out by Tan et al. (2002), very large Taiwanese firms suffer more from institutional pressures from Taiwan's government to not

[19] See, for instance, Agarwal (1980), and Blonigen (2005) for literature surveys.
[20] This may be caused by imperfections in the financial and capital markets.
[21] See also Blonigen (2005).

invest into China due to hostility across the Taiwan Strait. Thus, the effect of the firm's size should have an inverse U-shape. That is, the expected sign of the coefficient of $SIZE_i$ is positive but that of $SIZE_i*SIZE_i$ is negative.

It has been suggested that one of the important driving forces behind FDI is to seek a production location with low labor cost (Kojima (1973)). Since the wage rate in China is significantly lower than that in Taiwan, a labor-intensive firm will benefit more from investing in China. As a result, we expect that a firm's capital-labor ratio (KL_i) will be negatively related to its FDI activity. Finally, according to the OLI paradigm proposed by Dunning (1977), one of the three necessary conditions for a firm to undertake foreign direct investment is ownership advantage. Since Taiwan, relative to China, has a comparative advantage in high-tech industries (particularly the IT industries), these industries are more likely to expand their markets through FDI into China. However, the policy of "to take root in Taiwan" restricts high-tech industries' investment timing, types and amount in China. We define a high-tech dummy variable HT_i which takes a value 1 for the high technology industries, and 0 otherwise. The expected sign of its coefficient is ambiguous.

4. The data and empirical results

4.1 The data

The data on the dependent variable used in this paper are compiled from the "*Survey on Taiwanese Firms in Mainland China*", published by Taiwan's Investment Commission, Ministry of Economic Affairs (MOEAIC) in 2003 and 2004. It investigated all firms which invested in China for more than one year. This paper chooses 198 listed companies on Taiwan Stock Market from the sample of the survey. Taiwan Economic Journal (TEJ) database indicates that among 1,145 available listed companies on Taiwan's Stock Market, 672 companies invested in China before 2002. Thus, our sample firms account for 29.5% of all

Taiwanese firms investing into China. To avoid the problem of sample selection bias, we use a uniform distribution to randomly choose 139 companies from those listed firms that had not invested in China before 2002. Because these companies might have invested in China after 2002, they are treated as right-censored samples. Therefore, our final sample consists of 337 firms.

Taiwan government prohibited domestic firms from having any trade or investment relationship with China before 1987. These barriers in trade or investment were removed or lowered starting in 1987. We therefore analyze the timing of Taiwanese firms' entry into China during the period from 1987 to 2002. In other words, Taiwanese firms enter the risk set of entry from 1987, but there are 36 firms that were set up after 1987, and thus the risk set of these firms begins from the years of their establishment. The entry years are obtained from the government's official survey data. Figure 1 shows the distribution of entry years. The number of entries has increased considerably from 1993, reaching a peak in 2000.

As mentioned above, in order to test the validity of theoretical prediction, two dummy variables EX_M and EX_E are created. We separate the sample firms into three groups, according to their pre-FDI export ratios: market-seeking firms (firms with zero exports), export-substituting firms (firms with export ratios more than 80%), and other firms. The definition of these two variables are accordingly: (1) market-seeking firm dummy, EX_M, taking a value 1 for a firm with zero exports if the sales of the firm's subsidiary account for more than 80% of its total sale in China, and 0 otherwise; (2) export-substituting firm dummy, EX_E, taking a value 1 for a firm with a export ratio greater than 0.6 if the sales of its subsidiary account for more than 80% of the subsidiary's total sale in China, and 0 otherwise. According to these criteria, we have 23 market-seeking firms and 22 export-substituting firms in our sample.[22]

[22] To test the robustness of our empirical results, we have relaxed our criteria about investing firms by including

Several measures of trend and volatility of the real exchange rate have been proposed in the literature. Following Tsay (2002, p.229), we first use a modified average and a modified standard deviation of the monthly change in the logarithm of the real exchange rate to stand for the trend and volatility of the real exchange rates, which are designed to approximate a continuous-time geometric Brownian motion process. We then use a GARCH process to estimate the conditional mean and variance of the real exchange rate as the other measures of its trend and volatility, since some studies such as Pozo (1992) note that exchange rates often exhibit persistent behavior.[23] See Appendix 2 for details about the calculation of these measures.

Table 3 summarizes the distribution of the sample firms by industry. The electronics and electric industries account for significant shares of all sample firms as well as investing firms. Both shares are around 40%. Furthermore, most of export-substituting firms belong to electronic and electric appliances industries, but by contrast, most of market-seeking firms belong to services and food & beverage industries. It is worth noting that the export ratios of the sample firms scatter widely with a standard deviation of 30.8%, which allows us to separate our sample firms into three groups so as to test the validity of our theory. Summary statistics of these variables are summarized in Table 4.

4.2 Empirical results

Table 5 summarizes the estimation results of our empirical model.[24] The regression equations reported in columns 1 and 3 are our benchmark case, in which the dummy variables EX_M and EX_E that control for investing motives are not considered. In columns 2 and 4 we introduce these two dummy variables in order to test the validity of our theory.

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those firms with sales of its subsidiary accounting for more than 50% of the subsidiary's total sales in China. We find that the empirical results are basically the same.

[23] The measure of Tsay (2002) belongs to unconditional variance, and the measure of GARCH belongs to conditional variance.

[24] The estimation in Table 5 uses the method of Efron.

In column 1, both of the coefficients of σ_t and μ_t are positive, but not statistically significant, and the coefficient of $R_{t\text{-}1}$ is significantly negative. However, the results in column 2 reveal that there is considerable heterogeneity in the effects of the determinants of FDI among different types of FDI.

The effect of real exchange rate volatility on market-seeking FDI, as shown in the joint test of ($\alpha_1 + \alpha_2$), is significantly negative, while its effect on export-substituting FDI, as shown in the joint test of ($\alpha_1 + \alpha_3$), is significantly positive. As for the effect of real exchange rate, whereas its effect on market-seeking FDI, as shown in the joint test of ($\alpha_4 + \alpha_5$), is significantly positive, its effect on export-substituting FDI, as shown in the joint test of ($\alpha_4 + \alpha_6$), is significantly negative. It is also worth noting that, in contrast to the insignificant result in column 1, the effects of real exchange rate trend on market-seeking FDI and export-substituting FDI, as shown in the joint tests of ($\alpha_7 + \alpha_8$) and ($\alpha_7 + \alpha_9$), are both significantly positive. These results are consistent with the prediction of our theory. It also demonstrates that testing results without considering the heterogeneity in the investing motives might suffer from aggregation bias.

As for the control variables, the coefficients of firm's size ($SIZE_i$), source of funds ($FUND_i$), profit ($PF_{i,t}$), and R&D intensive ($R\&D_i$) are significantly positive. This indicates that Taiwanese firms that have a larger size, are funding from their parent companies, have higher profit rates, and have a higher R&D intensity tend to have higher incentive to invest into China earlier. Furthermore, the coefficient of $SIZE_i * SIZE_i$ is significantly negative, which suggests that the entry of very large Taiwanese firms into China might be deterred due to Taiwan government's policy. In addition, the coefficient of KL_i is significantly negative and the coefficient of HT_i is negative but not statistically significant, indicating that investing firms in labor-intensive or traditional industries are more likely to invest into China. In general, these results are consistent with previous studies. Finally, the results in columns 3 and 4 show that the empirical results in columns 1 and 2 are not qualitatively sensitive to different measures of the trend and volatility of real exchange rates.

To evaluate the relative importance of these covariates in the entry decision of investing firms, a useful formula is given by

$$\%\Delta h(t) = \frac{e^{\beta(x_i = X_1)} - e^{\beta(x_i = \bar{X})}}{e^{\beta(x_i = \bar{X})}} \times 100\ ,$$ [25]

where x_i is the ith covariate; $\bar{X}$ denotes the mean of x_i; and X_1 denotes a value of increasing x_i by 10% from its mean value. This equation states how many percentage increase (or decrease) in the probability of entry occurrence will be obtained from a 10% increase in the ith covariate.

Table 6 summarizes the estimation results about the magnitude of the covariates' effect on the hazard ratio. They reveal that the most important determinant of Taiwanese investment into China is the relative wage rate. The probability of Taiwanese firm's entry increases by about 50% when relative wage rate raises 10%. As for the exchange rate variables, the exchange rate level seems to have the largest effect on the hazard of entry occurrence. A 10% depreciation of NTD against RMB tends to increase the probability of the occurrence of market-seeking FDI by 19% while it may decrease the probability of the occurrence of export-substituting FDI by 11%. By contrast, a 10% increase in exchange rate volatility tends to increase the probability of export-substituting FDI by 13% while it may decrease the probability of market- seeking FDI by 8%. Other covariates, (e.g., exchange rate trend, marketing intensity, profit rate, R&D intensity, firm's size, and capital labor ratio), only have small influences on the entry decision. It also indicates that, compared to the case when *FUND*=0, the probability of a firm's entry is about 2.13 times greater if its parent company can fund the investment.

[25] See Box-Steffensmeier and Jones (2004, p.60).

To sum up, our empirical findings indicate that relative wage rates, the real exchange rate level and its trend as well as volatility have a significant impact on the timing of Taiwanese firms' investment into China. In particular, the relationship between real exchange rate volatility and the timing of FDI varies with the motives of investing firms, which suggests that it is important to consider this fact in investigating the determinants of foreign direct investment.

5. Conclusion

This paper theoretically and empirically examines how exchange rate uncertainty influences the timing of FDI. We develop an integrated model of FDI under uncertainty to illustrate the impact of exchange rate volatility on the FDI activity of an export-substituting firm versus a market-seeking firm. We show that while exchange rate uncertainty tends to delay the FDI activity of a market-seeking firm, it actually may accelerate the FDI activity of an export-substituting firm if the degree of risk aversion of the firm is high enough. In other words, the relationship between exchange rate uncertainty and FDI is generally indeterminate, depending on the FDI types. The rationale behind these results is that market-seeking FDI might increase the exposure of the firm's profits to exchange rate risk, while export-substituting FDI might reduce it. Our theoretical results can be viewed as a synthesis of many previous studies on this issue.

Firm-level data on Taiwanese firm's outward FDI into China over the period between 1987 and 2002 are employed to test the validity of our theoretical results. The empirical findings indicate that real exchange rate movements have had a significant impact on Taiwanese firms' investment into China. In general, the empirical results are consistent with the prediction of the theory. Our results reveal that the relationship between exchange rate uncertainty and FDI is crucially dependent on the motives of the investing firms. Hence, it is essential to consider this factor in an empirical model so that the testing results are free from aggregation bias.

Appendix 1: Proofs of Lemmas

Proof of Lemma 1

Using Equations (8a) and (8b), it can be shown that

$$\frac{\partial^2 R_L}{\partial\sigma\partial a_p} = \Phi\left[-\frac{\sigma}{\rho-2\mu}\left(1+\frac{2\mu+\sigma^2}{2\sqrt{2\rho\sigma^2+(\mu-0.5\sigma^2)^2}}\right)+\frac{2\sigma}{\rho-2\mu-\sigma^2}(1+\alpha)\right] \tag{A1}$$

and

$$\frac{\partial^2 R_L}{\partial\mu\partial a_p} = \Psi\left[\frac{\rho-\mu}{\sqrt{2\rho\sigma^2+(\mu-0.5\sigma^2)^2}}+(1+\alpha)\left(\frac{\rho-2\mu-0.5\sigma^2}{\rho-2\mu-\sigma^2}\frac{4(\rho-\mu)}{\rho-2\mu}-1\right)\right] \tag{A2}$$

where $\Phi = \frac{R_0^2\alpha(\rho-\mu)[P_f^2-(P_f-W_f)^2]}{2W_f(1+\alpha)^2(\rho-2\mu-\sigma^2)} > 0$; $\Psi = \frac{R_0^2\alpha\gamma[P_f^2-(P_f-W_f)^2]}{2W_f(1+\alpha)^2} > 0$. Since we assume $\rho > 2\mu+\sigma^2$, $\frac{\rho-2\mu-0.5\sigma^2}{\rho-2\mu-\sigma^2} > 1$ and $\frac{4(\rho-\mu)}{\rho-2\mu} > 1$. Thus, $\partial^2 R_L/\partial\mu\partial a_p > 0$. Regarding Equation (A1), since $\frac{\sigma}{\rho-2\mu} < \frac{2\sigma}{\rho-2\mu-\sigma^2}$, $\partial^2 R_L/\partial\sigma\partial a_p > 0$ if $\alpha > \frac{2\mu+\sigma^2}{2\sqrt{2\rho\sigma^2+(\mu-0.5\sigma^2)^2}}$. Note that

$$\alpha - \frac{2\mu+\sigma^2}{2\sqrt{2\rho\sigma^2+(\mu-0.5\sigma^2)^2}}$$

$$= \frac{\alpha}{4\rho}\left[(\rho-2\mu-\sigma^2)+\frac{3\rho\sqrt{2\rho\sigma^2+(\mu-0.5\sigma^2)^2}+2(\mu+0.5\sigma^2)(\mu-0.5\sigma^2)}{\sqrt{2\rho\sigma^2+(\mu-0.5\sigma^2)^2}}\right]$$

Since $3\rho > 2(\mu+0.5\sigma^2)$ and $\sqrt{2\rho\sigma^2+(\mu-0.5\sigma^2)^2} > |\mu-0.5\sigma^2|$ under the assumption $\rho > 2\mu+\sigma^2$, thus $\alpha > \frac{2\mu+\sigma^2}{2\sqrt{2\rho\sigma^2+(\mu-0.5\sigma^2)^2}}$. Consequently, $\partial^2 R_L/\partial\sigma\partial a_p > 0$. ■

Proof of Lemma 2

From Equation (12b), we have

$$\frac{\partial^2 R_H}{\partial\mu\partial a_p} = \Gamma\left[\frac{\rho-\mu}{\sqrt{2\rho\sigma^2+(\mu-0.5\sigma^2)^2}}+(\beta-1)\left(\frac{\rho-2\mu-0.5\sigma^2}{\rho-2\mu-\sigma^2}\frac{4(\rho-\mu)}{\rho-2\mu}-1\right)\right] \tag{A3}$$

where $\Gamma = \frac{\beta\gamma(P_f-W_f)}{(\beta-1)^2} > 0$. Similar to Equation (A2), we have $\partial^2 R_H/\partial\mu\partial a_p > 0$.

Appendix 2: Data Description

The level of the real exchange rate, *R,* is the average bilateral real exchange rate, expressed in unit of NTD per RMB. It is calculated with a nominal exchange rate of NTD to USD, and that of RMB to USD; it is deflated with Taiwan's CPI and China's CPI, respectively. The data of CPI are compiled from the database of Taiwan Economic Journal (TEJ) and nominal exchange rates are from the Central Bank of China (Taiwan). The real relative wage index, *WAGE*, defined as the ratio of the real annual average wage of China over the real annual average wage of Taiwan, is compiled from the database of TEJ.

Two measures of trend and volatility of the real exchange rate are used. First, μ_{Tasy} and σ_{Tasy} are defined respectively as a modified average and a modified standard deviation of the monthly changes in the log of the real exchange rate over the past 24 months; that is

$$\sigma_{Tasy,t} = \frac{1}{\sqrt{\Delta}}\left[\frac{1}{T-1}\sum_{j=1}^{T}\left(r_{t-j+1} - \frac{1}{T}\sum_{j=1}^{T} r_{t-j+1}\right)^2\right]^{1/2}, \quad \mu_{Tasy,t} = \frac{1}{T\cdot\Delta}\sum_{j=1}^{T} r_{t-j+1} + \frac{\sigma^2_{Tasy,t}}{2},$$

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

Second, a GARCH process is adopted to estimate the volatility. With data covering the period from 1985:01 to 2002:12, we conduct the Augmented Dickey Fuller (ADF) test. The test result rejects the null hypothesis of unit root for $\Delta \ln R_t$. The estimated GARCH model is as follows:

$$\Delta \ln R_t = \ln R_t - \ln R_{t-1} = \underset{(-1.24)}{-0.0031} + u_t,$$

$$h_t = \underset{(18.00)}{0.0012} + \underset{(9.54)}{0.3389} u_{t-1}^2 - \underset{(-4.22)}{0.1049} h_{t-1},$$

where $\Delta \ln R_t$ is the first difference of the real exchange rate; and h_t is the conditional variance of the error term u_t. The numbers in parentheses are t-statistics. Thus, μ_{GARCH} and σ_{GARCH} are defined respectively as

$$\sigma_{GARCH,t} = \left[\frac{1}{T}\sum_{j=1}^{T} h_{t-j+1}\right]^{1/2}, \mu_{GARCH,t} = \frac{1}{T}\sum_{j=1}^{T} u_{t-j+1}.$$

The monthly nominal exchange rates are compiled from Central Bank of China (Taiwan) and CPI are compiled from the database of TEJ.

The data on the duration of a firm's FDI, sources of funds (*FUND*) and sales of its subsidiary are obtained from "*Survey on Taiwanese Firms in Mainland China*", 2003~2004, Investment Commission, Ministry of Economic Affairs. The following variables are compiled from the database of TEJ: marketing intensive (*MKT*), sales of the parent company (*SIZE*), profit rate (*PF*), R&D intensity (*R&D*), capital-labor ratio (*KL*) and export ratio. The definition of high-tech industries follows that used in "*The White Book of Industrial Technology*", 1998, Department of Industrial Technology, Ministry of Economic Affairs.

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Table 1 Expected signs of the determinants of FDI

Types \ Variables		Exchange Rate Level (R)	Exchange Rate Trend (μ)	Exchange Rate Volatility (σ)	Sunk Costs (k)	Foreign Wage Rate (W_f)	Domestic Wage Rate (W_d)
Export-substituting FDI	risk neutrality	-	-	-	-	-	+
	risk aversion	-	?	?	-	-	+
Market-seeking FDI	risk neutrality	+	+	-	-	-	
	risk aversion	+	?	-	-	?	

Table 2 Definition of the explanatory variables and their expected signs

Explanatory Variable	**Definition**	**Expected sign**	
		Market-seeking FDI	**Export-substituting FDI**
Exchange rate volatility (σ_t)	Volatility of the real exchange rate	-	?
Exchange rate trend (μ_t)	Trend of the real exchange rates	?	?
Exchange rate (R_{t-1})	One-period lagged real exchange rate of NTD currency against RMB	+	-
Relative wage rate ($WAGE_{t-1}$)	Ratio of China's one-period lagged real wage rate over Taiwan's one-period lagged real wage rate	?	-
Marketing intensity (MKT_i)	Average ratio of marketing expenditures to total sales of the firm over the period 1987-1991★ (%)	-	-
<u>Control variables</u>			
Profit rate ($PF_{i,t}$)	Average ratio of profits to total sales of the firm over the period 1987-1991★ (%)	+	
Source of funds ($FUND_i$)	Dummy variable, whose value is 1 for the firms that are provided with funds from parent; 0, otherwise	+	
R&D intensity ($R\&D_i$)	Average ratio of R&D expenditures to total sales of the firm over the period 1987-1991★ (%)	+	
Firm size ($SIZE_i$)	Average sales of the firm over the period 1987-1991★ (billion NTD)	+	
Squares of firm size (SIZEi* SIZEi)		-	
Capital-labor ratio(KL_i)	Average ratio of total fixed assets to the number of employees of the firm over the period 1987-1991★ (million NTD per worker)	-	
High-technology industry (HT_i)	Dummy variable, whose value is 1 for the electronics & electric appliances, chemicals and precision instruments industries; 0 otherwise.	?	

Notes: ★If a firm was established after 1987, then the ratios computed are based on the data for the five years beginning from its establishment year.
(+) represents early investment; (-) represents delaying investment; (?) represents undetermined.

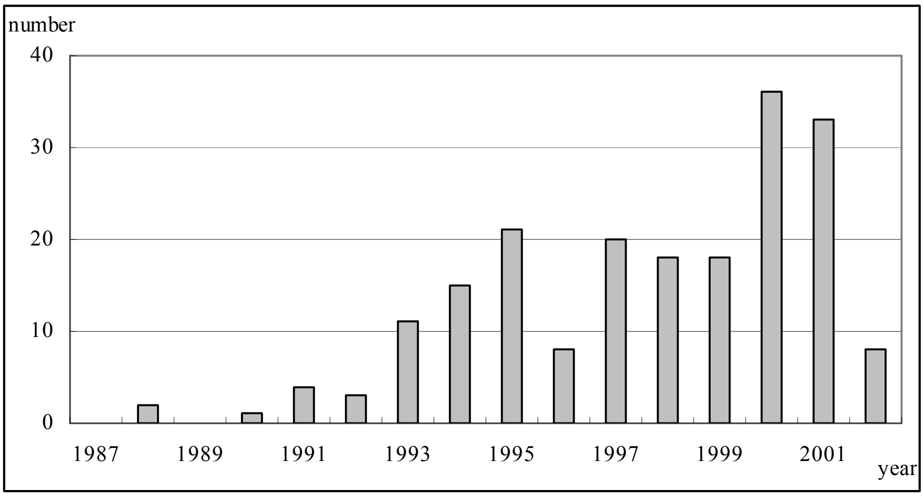

Figure 1 Entry years of sample firms

Table 3 Distribution of sample firms by industry

Industry	Subtotal	Investing firms	Market-seeking firms	Export-substituting firms
Food & Beverage	11	7	7	0
Chemicals and Plastic Products	27	19	1	2
Electronic & Electric Appliances	153	80	1	15
Other Manufacturing	76	46	5	5
Services	54	38	8	0
Others	16	8	1	0
Total	337	198	23	22

Note: The industry of an investing firm is the industry which its parent company belongs to.

Table 4 Summary statistics

Variables	Mean	Min	Max	Standard deviation
Real exchange rate	3.6895	2.6263	4.5714	0.5576
Real relative wage rate	0.0648	0.0454	0.1198	0.0218
Marketing intensity (%)	6.6%	0.0%	67.8%	8.4%
Firm size (billion NTD)	1.9198	0.0069	138.29	8.5817
Profit rate (%)	5.1%	-178.0%	61.8%	19.2%
R&D intensity (%)	0.8%	0.0%	33.1%	2.7%
Capital-labor ratio (million NTD per worker)	2.5517	0.0545	49.00	3.8554
Exports ratio of export-substituting firms (%)	83.5%	64.7%	100.0%	12.2%

Table 5 The estimation of the determinants of the timing of FDI: Cox model

Covariates \ Equations	Tsay (2002)				GARCH (1,1)			
	(1) Coefficients		(2) Coefficients		(3) Coefficients		(4) Coefficients	
$\sigma_t(\alpha_1)$	4.3830	(1.54)	5.2413[c]	(1.88)	23.07	(1.57)	27.29[c]	(1.89)
$EX_M*\sigma_t(\alpha_2)$			-10.1228[a]	(-6.06)			-49.59[a]	(-5.50)
$EX_E*\sigma_t(\alpha_3)$			1.7716	(0.66)			5.8598	(0.44)
$R_{t-1}(\alpha_4)$	-0.3988[a]	(-2.92)	-0.2342	(-1.55)	-0.3821[a]	(-3.24)	-0.2012	(-1.44)
$EX_M*R_{t-1}(\alpha_5)$			0.7020[a]	(7.54)			0.6676[a]	(6.00)
$EX_E*R_{t-1}(\alpha_6)$			-0.0925	(-1.27)			-0.1071[c]	(-1.88)
$\mu_t(\alpha_7)$	0.0314	(0.03)	-0.3465	(-0.36)	-0.8448	(-0.03)	-9.9318	(-0.45)
$EX_M*\mu_t(\alpha_8)$			3.9059[a]	(4.72)			92.91[a]	(4.87)
$EX_E*\mu_t(\alpha_9)$			2.0351[a]	(13.8)			53.92[a]	(8.10)
$WAGE_{t-1}(\alpha_{10})$	-108.69[a]	(-6.69)	-110.91[a]	(-6.99)	-110.14[a]	(-6.69)	-112.02[a]	(-6.91)
$MKT_i(\beta_1)$	-1.0365[a]	(-4.37)	-3.2747[a]	(-2.96)	-1.0352[a]	(-4.39)	-3.3328[a]	(-2.86)
$PF_{i,t}(\alpha_{11})$	0.0071[a]	(5.58)	0.0108[a]	(6.41)	0.0071[a]	(5.36)	0.0107[a]	(6.44)
$FUND_i(\beta_2)$	0.7722[a]	(2.64)	0.7554[a]	(3.98)	0.7723[a]	(2.64)	0.7545[a]	(4.06)
$R\&D_i(\beta_3)$	0.1004[c]	(1.88)	0.0954	(1.59)	0.1005[c]	(1.89)	0.0991	(1.59)
$SIZE_i(\beta_4)$	0.1775[a]	(6.33)	0.0914[c]	(1.93)	0.1775[a]	(6.35)	0.0935[c]	(1.97)
$SIZE_i*SIZE_i(\beta_5)$	-0.0056[a]	(-8.78)	-0.0032[b]	(-2.40)	-0.0056[a]	(-8.81)	-0.0032[b]	(-2.45)
$KL_i(\beta_6)$	-0.1343[a]	(-8.60)	-0.0926[a]	(-5.15)	-0.1343[a]	(-8.59)	-0.0924[a]	(-5.11)
$HT_i(\beta_7)$	-0.6209	(-0.89)	-0.6624	(-0.91)	-0.6208	(-0.89)	-0.6644	(-0.91)
$\alpha_1+\alpha_2$			-4.8815[a]	(-3.16)			-22.30[a]	(-2.88)
$\alpha_1+\alpha_3$			7.0129[b]	(2.20)			33.15[b]	(2.04)
$\alpha_4+\alpha_5$			0.4678[a]	(2.81)			0.4564[a]	(2.83)
$\alpha_4+\alpha_6$			-0.3266[b]	(-2.23)			-0.3083[b]	(-2.32)
$\alpha_7+\alpha_8$			3.5594[a]	(9.21)			82.98[a]	(7.71)
$\alpha_7+\alpha_9$			1.6886[b]	(2.09)			43.99	(1.55)
Likelihood ratio test	205.66[a]		232.37[a]		204.90[a]		232.79[a]	

Notes: 1. The t-statistics are in parentheses; superscripts a, b and c denote that the test statistics are significant at the 1%, 5% and 10% levels, respectively. 2. Tsay (2002) and GARCH (1,1) represent two different measures of trend and volatility of real exchange rates.

Table 6 The effect of covariate changes on hazard ratio

Covariates	Tsay (2002)			GARCH(1,1)		
	Mean	Increase 10% from mean	% change $h(t)$	Mean	Increase 10% from mean	% change $h(t)$
<u>Continuous variables</u>						
$\sigma_t(\alpha_1)$:*O*	0.1761	0.1937	9.67	0.0378	0.0416	10.87
$\sigma_t(\alpha_1+\alpha_2)$:*M*	0.1761	0.1937	-8.24	0.0378	0.0416	-8.08
$\sigma_t(\alpha_1+\alpha_3)$:*E*	0.1761	0.1937	13.14	0.0378	0.0416	13.35
$R_{t-1}(\alpha_4)$:*O*	3.6895	4.0585	-8.28	3.6895	4.0585	-7.15
$R_{t-1}(\alpha_4+\alpha_5)$:*M*	3.6895	4.0585	18.84	3.6895	4.0585	18.34
$R_{t-1}(\alpha_4+\alpha_6)$:*E*	3.6895	4.0585	-11.35	3.6895	4.0585	-10.75
$\mu_t(\alpha_7)$:*O*	-0.0275	-0.0248	-0.10	0.0012	0.0013	-0.12
$\mu_t(\alpha_7+\alpha_8)$:*M*	-0.0275	-0.0248	0.98	0.0012	0.0013	1.00
$\mu_t(\alpha_7+\alpha_9)$:*E*	-0.0275	-0.0248	0.47	0.0012	0.0013	0.53
$WAGE_{t-1}(\alpha_{10})$	0.0648	0.0713	-51.26	0.0648	0.0713	-51.61
$MKT_i(\beta_1)$	0.0660	0.0726	-2.14	0.0660	0.0726	-2.18
$PF_{i,t}(\alpha_{11})$	0.0510	0.0561	0.01	0.0510	0.0561	0.01
$R\&D_i(\beta_3)$	0.0080	0.0088	0.01	0.0080	0.0088	0.01
$SIZE_i(\beta_4)$	1.9198	2.1118	1.77	1.9198	2.1118	1.81
$KL_i(\beta_6)$	2.5517	2.8069	-2.34	2.5517	2.8069	-2.33
<u>Dummy variables</u>						
$FUND_i(\beta_2)$	0	1	112.85	0	1	112.65
$HT_i(\beta_7)$	0	1	-48.44	0	1	-48.54

Note: *O*, *M*, and *E* represent other firms, market-seeking firms, and export-substituting firms, respectively.