The Impact of Exchange Rate Movements on Foreign Direct Investment: Are There Third Country Effects?

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ABSTRACT

This paper applies a real options model to examine the impact of exchange rate movements on foreign direct investment (FDI) activity both theoretically and empirically. In contrast to previous studies, the effects of exchange rate changes in the host country as well as third countries are analyzed herein. It is shown that while the depreciation of the host country's currency stimulates cost-saving FDI activity, the depreciation of the third country's currency deters it. In addition, exchange rate uncertainty in the host country and third countries may have a positive impact on FDI activity if the correlation between these countries' currencies is high enough. Finally, the real wage rates of the host country relative to those of the third countries are negatively related to FDI activity. This paper employs the panel data on Taiwan's outward FDI in China and Southeast Asian countries over the period 1985-2006 to test the validity of the theoretical results. The empirical results are generally consistent with the prediction of the theory. These results suggest that the third country's effects of the exchange rate movements on FDI activity do exist.

Keywords: FDI, exchange rate, real options, third country effects
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1. Introduction

In the past few decades, outward foreign direct investment (FDI) has been increasing sharply in many countries, but one of its distinct features is that it has fluctuated considerably over time. For instance, OECD International Direct Investment Database indicates that FDI inflows into the United States increased by 159% in 1993 and 70% in 1998, but decreased by 48% in 2001 and 57% in 2002. A similar situation occurred in many countries. This phenomenon is inexplicable from the perspectives of traditional theory. The traditional theory of FDI emphasizes the influence of ownership, location, or internalization advantages, which can explain the long-run changes in FDI, but not its short-run fluctuation.

Since exchange rates, an important factor determining international capital movement, have also varied sharply over time in many countries, several recent studies suggest that one possible explanation for the large short-run fluctuation of FDI is due to the movements of exchange rates. However, evidence is still mixed. For instance, Bell and Campa (1997), Campa (1993), Darby et al. (1999), and Kiyota and Urata (2004) find that exchange rate uncertainty discourages FDI activity, while Cushman (1985) and Goldberg and Kolstad (1995) suggest that exchange rate uncertainty encourages it. Chen et al. (2006) and Lin et al. (2006) argue that the conflicting results in previous studies are attributable to the diversity in investing motives, finding that exchange rate uncertainty is positively related to FDI if the investing firms attempt to substitute FDI for their exports. Furthermore, exchange rate uncertainty might be negatively related to FDI if the investing firms are seeking new markets for their products or if they attempt to use cheaper inputs in the host countries for production and then export back to their home countries.

One limitation in most previous studies is that the third country effects of exchange rate movements are ignored. In determining its overseas investment, a firm may need to

choose one location from several potential destinations. Under such circumstances, the movements of exchange rates in the potential host countries are of important consideration. This possibility has been examined in several recent studies. For instance, Becker and Hall (2003) find that the increase in the correlation between the Euro and British Pound encourages firms to change their R&D investment from the Euro area to the U.K. Barrel et al. (2003) also indicate that the increase in the correlation among the U.S. dollar, Euro, and British Pound encourages firms to move their FDI from the Euro area to the U.K. However, theoretical or empirical studies on the third country effects of exchange rates are still rather limited.

To fill this gap in the literature, this paper's purpose is to examine the third country effects of exchange rate movements on FDI both theoretically and empirically. We first apply a three-country model to investigate the relation between exchange rates and a firm's choice of its investment location. We find that the correlation between the exchange rates of the host country and the third country is important in determining a firm's overseas investment activity. The data on Taiwan's outward investment between 1985 and 2006 are then used to test the validity of the theoretical results. Our empirical results turn out to be consistent with the prediction of our theoretical model.

The remainder of the paper proceeds as follows. The following section presents Dixit and Pindyck's real options model and illustrates the effects of exchange rate movements on FDI activity. Our empirical model and estimation method are discussed in Section 3, 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 cost-saving FDI

Dixit-Pindyck's (1994) real options model is extended here to re-examine the

relationship between exchange rate and FDI. Suppose that a risk-neutral firm is a price taker and faces a market price P in terms of the home country's currency.[1] Moreover, it produces a unit flow of output at fixed marginal cost per period. For simplicity, we assume that the variable costs are comprised only of labor cost and the input-output coefficient is fixed to be one. Therefore, the wage rate can be treated as the variable costs.

Prior to implementing FDI, a firm produces goods at its home country (country 1) and sells products to its target market. Hence, its profit flows in terms of the home country's currency per period are:

$$\pi^0 = P - W_1, \tag{1a}$$

where π is profit, the superscript 0 represents the pre-FDI state, and W_1 is the domestic wage rate which represents the variable costs of domestic production.

The most popular destination of Taiwan's FDI is to low-wage countries in general, and China in particular. Hence, it is assumed here that the motive for FDI is to reduce the investing firm's production costs. If the firm invests into country 2 (host country) and serves the home market from its foreign subsidiary, then its profit flows become:

$$\pi^1 = P - W_2 \cdot R, \tag{1b}$$

where superscript 1 represents the post-FDI state, W_2 is the host country's wage rate in terms of its currency, and R is the exchange rate expressed in units of home currency per host country's currency. From Equations (1a) and (1b), the change in profits, $\Delta\pi$, from implementing FDI can be written as follows:

$$\Delta\pi_2 = \pi^1 - \pi^0 = -W_2 R - W_1, \tag{2a}$$

where subscript 2 represents FDI in the country 2.

The firm can alternatively invest into another country - namely, a third country (country 3). Applying a similar procedure as above, the change in profits from

[1] The target market could be the home market or foreign market.

implementing FDI in country 3 can be written as:

$$\Delta\pi_3 = -W_3 S - W_1, \tag{2b}$$

where subscript 3 represents FDI in the country 3, W_3 is the third-country's wage rate in terms of its currency, and S is the exchange rate expressed in units of home currency per country 3's currency.

Assume that the firm can invest either in the countries 2 or 3. It is obvious that the change in profit flows from implementing FDI in country 3 represents the firm's opportunity cost of investing in country 2. Thus, the net economic profits from investing in the country 2, $\Delta\tilde{\pi}$, are:

$$\Delta\tilde{\pi} = \Delta\pi_2 - \Delta\pi_3 = -W_2 R + W_3 S. \tag{3}$$

It is assumed that the exchange rates R and S follow the process of an exogenously geometric Brownian motion:

$$\frac{dR}{R} = \mu_R dt + \sigma_R dz_R \tag{4a}$$

and

$$\frac{dS}{S} = \mu_S dt + \sigma_S dz_S. \tag{4b}$$

Here, μ_R and μ_S are respectively the growth rates of the exchange rates R and S, σ_R and σ_S are respectively the volatilities of the exchange rates R and S, t is the time path, and z_R and z_S are Wiener process.[2] Furthermore, the correlation between these two exchange rates, ρ, can be written as:

$$\mathrm{E}\left[dz_R dz_S\right] = \rho \cdot dt. \tag{4c}$$

From Equation (3), if the firm invests in the country 2 and stays there forever, then the expected present value of the firm, ξ, is:

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[2] The subscript t of R, S, and π is suppressed in this section for simplicity.

$$\xi(R,S) = -\frac{W_2}{\delta - \mu_R} R + \frac{W_3}{\delta - \mu_S} S, \tag{5}$$

where δ is the firm's discount rate. For the purpose of convergence, we assume $\delta > \mu_S$ and $\delta > \mu_R$. It is obvious from Equation (5) that an appreciation of the country 2's currency (i.e., an increase in *R*) or a depreciation of the country 3's currency (i.e., a decrease in *S*) causes a reduction in $\xi(R,S)$, thus deterring the firm's FDI activity into country 2.

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 country 2 after investing a lump sum *k*, or keep producing at its home country and keep the right to invest overseas in the next period. Hence, in each period the firm faces a binary decision problem as follows:

$$V(R,S) = \max\left\{\xi(R,S) - k \cdot R, \frac{1}{1+\delta\Delta t} E\left[V(R',S') \middle| (R,S)\right]\right\}, \tag{6}$$

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

Since π is homogeneous of degree one in (*R*,*S*), $V(R,S)$ is also homogeneous of degree one in (*R*,*S*). Following the procedure used in Dixit and Pindyck (1994, chapter 6), Equation (6) can be rewritten as:

$$v(r) = \max\left\{\tilde{\xi}(r) - k \cdot r, \frac{1}{1+\delta\Delta t} E\left[v(r') \middle| (r)\right]\right\}, \tag{7}$$

where $r = R/S$, $V(R,S) = S \cdot v(r)$, and $\xi(R,S) = S \cdot \tilde{\xi}(r)$.

Since the profit function is a decreasing function of *r*, there is a cutoff point, r^*, at

which if $r < r^*$, then the net entry value is greater than the value of the option to wait.[3] Thus, the firm's optimal decision is to invest now in the country 2. Using value-matching and smooth-pasting conditions, we have:

$$r^* = \frac{W_3(\delta - \mu_R)}{(\delta - \mu_S)\left[W_2 + k(\delta - \mu_R)\right]} \frac{\alpha}{\alpha + 1}, \tag{8}$$

where

$$\alpha = \frac{(\tilde{\mu} - 0.5\tilde{\sigma}^2) + \sqrt{(\tilde{\mu} - 0.5\tilde{\sigma}^2)^2 + 2\tilde{\sigma}^2\tilde{\delta}}}{\tilde{\sigma}^2} > 0,^{4}$$

$$\tilde{\sigma}^2 = \sigma_R^2 - 2\rho\sigma_R\sigma_S + \sigma_S^2 > 0, \quad \tilde{\mu} = \mu_R - \mu_S, \quad \tilde{\delta} = \delta - \mu_S > 0.$$

The higher the value of r^* is, the higher the probability will be that r is smaller than r^*. Hence, the firm has a higher incentive to invest into country 2 earlier.

Proposition 1 An increase in the correlation of exchange rates *R* and *S* tends to stimulate FDI activity.

Proof. From Equation (8), we have:

$$\frac{\partial r^*}{\partial \rho} = -2\sigma_R\sigma_S \frac{r^*}{\alpha(\alpha + 1)} \frac{\partial \alpha}{\partial \tilde{\sigma}} > 0.$$

According to Chen et al. (2006, p.285), $\partial\alpha/\partial\tilde{\sigma} < 0$. Therefore, $\partial r^*/\partial\rho > 0$. ■

The economic intuition behind Proposition 1 is straightforward. In our analytical framework, under the assumption of risk neutrality, the increase in the uncertainty of profit flows might induce the firm to postpone its investment decision. Furthermore, the correlation between the exchange rates of the host country and the third country, *ρ,* affects

[3] Intuitively, the firm will wait when *R* is high or *S* is low, and invest when *R* becomes sufficiently low for a given *S*, or *S* becomes sufficiently high for a given *R*.

[4] See Dixit (1989a, p.626).

the degree of uncertainty about profit flows. When $\rho > 0$, an appreciation of the host country's currency tends to associate with an appreciation of the third country's currency. In contrast, when $\rho < 0$, an appreciation of the host country's currency tends to associate with a depreciation of the third country's currency. Recall that profits from investing in the country 3 are the opportunity cost of investment in the country 2. It is clear from Equation (3), if R and S move in the same direction, that the variability of profit flows will diminish and vice versa. Hence, an increase in the correlation of these two exchange rates will induce the firm to invest earlier.

Proposition 2 An increase in the volatility of exchange rate *R* may stimulate FDI activity in the country 2 if the variability of the country 2's exchange rate is smaller than that of the country 3 and the correlation between *R* and *S* is high enough - that is, $\partial r^* / \partial \sigma_R > 0$ if $\rho > \sigma_R / \sigma_S$.

Proof. From Equation (8), it can be shown that:

$$\frac{\partial r^*}{\partial \sigma_R} = 2(\sigma_R - \rho\sigma_S)\frac{r^*}{\alpha(\alpha+1)}\frac{\partial \alpha}{\partial \tilde{\sigma}}.$$

According to Chen et al. (2006, p.285), $\partial \alpha / \partial \tilde{\sigma} < 0$. Therefore, $\partial r^* / \partial \sigma_R > 0$ if $\rho > \sigma_R / \sigma_S$. ■

Since $\rho \le 1$, the conditions for $\partial r^* / \partial \sigma_S > 0$ to hold are $\sigma_R < \sigma_S$ and $\rho > \sigma_R / \sigma_S$. The economic intuition behind Proposition 2 is as follows. When $\rho > 0$, the direct effect of an increase in σ_R will deter FDI activity. However, there exists an indirect effect of an increase in σ_R through the interaction effect of exchange rates, which diminishes the variability of net profit flows from investing in the country 2. Hence, if the correlation is high enough, then the indirect effect dominates the direct effect, thus stimulating FDI

activity. In contrast, when $\rho < 0$, an increase in either σ_R or σ_S will add to the variability of net profit flows from investing in the country 2, thus deterring FDI activity there. By the same token, we summarize a similar result in Proposition 3, regarding the impact of the country 3's exchange rate variability on investing into the country 2.

Proposition 3 An increase in the volatility of exchange rate *S* may stimulate FDI activity in the country 2 if the variability of the country 3's exchange rate is smaller than that of the country 2 and the correlation between *R* and *S* is high enough - that is, $\partial r^* / \partial \sigma_S > 0$ if $\rho > \sigma_S / \sigma_R$.

Proof. From Equation (8), we have:

$$\frac{\partial r^*}{\partial \sigma_S} = 2\left(\sigma_S - \rho\sigma_R\right)\frac{r^*}{\alpha(\alpha+1)}\frac{\partial \alpha}{\partial \tilde{\sigma}}.$$

Similar to the proposition 1, $\partial r^* / \partial \sigma_S > 0$ if $\rho > \sigma_S / \sigma_R$. ■

Proposition 4 An increase in the trend of exchange rate *R* tends to deter FDI activity if the sunk investment costs are not too high - that is, $\partial r^* / \partial \mu_R < 0$ if $k < W_2 \cdot \psi / (\delta - \mu_R)^2$.

Proof. From Equation (8), we have:

$$\frac{\partial r^*}{\partial \mu_R} = \frac{r^* \tilde{\psi}}{(\delta - \mu_R)(1+\alpha)\left[W_2 + k(\delta - \mu_R)\right]\sqrt{(\tilde{\mu} - 0.5\tilde{\sigma}^2)^2 + 2\tilde{\sigma}^2\tilde{\delta}}},$$

where

$$\tilde{\psi} = (\delta - \mu_R)^2 k - W_2 \cdot \psi, \text{ and}$$

$$\psi = -\delta + \mu_R + (1+\alpha)\sqrt{(\tilde{\mu} - 0.5\tilde{\sigma}^2)^2 + 2\tilde{\sigma}^2\tilde{\delta}}.$$

Since $\delta > \mu_S$:

$$\psi\big|_{\delta=\mu_S} = \begin{cases} \dfrac{2\tilde{\mu}^2}{\tilde{\sigma}^2} > 0 & \text{if } \tilde{\mu} > 0.5\tilde{\sigma}^2 \\ 0.5\tilde{\sigma}^2 > 0 & \text{if } \tilde{\mu} < 0.5\tilde{\sigma}^2 \end{cases}$$

and

$$\frac{\partial \psi}{\partial \delta} = \tilde{\sigma}^2 \left(\alpha + \frac{1}{\sqrt{(\tilde{\mu} - 0.5\tilde{\sigma}^2)^2 + 2\tilde{\sigma}^2 \tilde{\delta}}} \right) > 0 .$$

Thus, $\psi > 0$. Therefore, $\partial r^* / \partial \mu_R < 0$ if $k < W_2 \cdot \psi / (\delta - \mu_R)^2$. ■

Proposition 4 indicates that the timing of FDI is related to two opposite forces associated with exchange rate movements. The trend of the host country's exchange rate, μ_R, represents its growth rate. The expected increase in the exchange rate implies that production will be more costly, which deters the firm's FDI activity. However, the lump sum investment costs are higher if the investment is implemented in the later period when the exchange rate is expected to rise. This effect induces the firm to invest earlier. Moreover, the larger the lump sum investment costs, the higher the latter effect will be. Proposition 4 suggests that if the lump sum investment costs are not large enough, the former effect of the change in μ_R will dominate the latter, hence deterring FDI activity.

Proposition 5 A firm will accelerate its FDI activity in the country 2 when the trend of exchange rate *S* rises.

Proof. From Equation (8), we have:

$$\frac{\partial r^*}{\partial \mu_S} = \frac{r^* \phi}{(\delta - \mu_S)\alpha \sqrt{(\tilde{\mu} - 0.5\tilde{\sigma}^2)^2 + 2\tilde{\sigma}^2 \tilde{\delta}}},$$

where $\phi = -\delta + \mu_S + \alpha \sqrt{(\tilde{\mu} - 0.5\tilde{\sigma}^2)^2 + 2\tilde{\sigma}^2 \tilde{\delta}}$.

Since $\delta > \mu_S$, $\phi\big|_{\delta=\mu_S} = \alpha \sqrt{(\tilde{\mu} - 0.5\tilde{\sigma}^2)^2 + 2\tilde{\sigma}^2} > 0$, and

$$\frac{\partial \phi}{\partial \delta} = \frac{\alpha \tilde{\sigma}^2}{\sqrt{(\tilde{\mu} - 0.5\tilde{\sigma}^2)^2 + 2\tilde{\sigma}^2 \tilde{\delta}}} > 0.$$

Hence, $\phi > 0$. Therefore, $\partial r^* / \partial \mu_S > 0$. ■

Similar to Proposition 4, the economic intuition behind Proposition 5 is that an increase in μ_S implies that the production costs in the country 3 will increase, which raises the relative advantage of investing in the country 2 instead of the country 3.

Proposition 6 Sunk investment costs and the country 2's wage rate are negatively related to the FDI activity - that is, $\partial r^* / \partial k < 0$ and $\partial r^* / \partial W_2 < 0$.

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

Proposition 7 Country 3's wage rate is positively related to FDI activity - that is, $\partial r^* / \partial W_3 > 0$.

Proof. The proof is straightforward, and thus is omitted.

The intuition behind Proposition 6 and Proposition 7 is clear. The higher the country 2's wage rate is, or the higher the sunk investment costs are, and the lower the net profits from FDI in the country 2 will be. Therefore, the firm will delay its FDI activity. In contrast, the higher the country 3's wage rate is, the lower the opportunity cost of investing in the country 2 will be, thus stimulating FDI activity. Table 1 summarizes the theoretical results from previous propositions.

3. Empirical model

Based on this paper's theoretical framework, the following empirical model is

established:

$$\begin{aligned} FDI_{it} = {} & \alpha_i + \beta_1 R_{i,t-1} + \beta_2 S_{i,t-1} + \beta_3 \mu_{R,it} + \beta_4 \mu_{S,it} + \beta_5 \sigma_{R,it} + \beta_6 \sigma_{S,it} \\ & + \beta_7 \rho_{it} + \beta_8 \sigma_{R,it} \times D_{R,it} + \beta_9 \sigma_{S,it} \times D_{S,it} \\ & + \beta_{10} W_{2,it} / W_{3,it} + \beta_{11} DCH_{it} + \beta_{12} D78_t + \varepsilon_{it} \end{aligned} \tag{9}$$

Here, subscript i refers to countries, subscript t refers to time periods, α_i and β_j $(j = 1,...,12)$ are parameters, and ε_{it} represents disturbance terms. To control for country-specific effects, country dummies are included in Equation (9). The definition of the variables in Equation (9) is explained as follows:

FDI_{it}: the desired FDI of country i at time t, which is divided by the host country's GDP to control for changes in its size.

$R_{i,t-1}$: the one-period lagged real exchange rate of Taiwan's currency (New Taiwan Dollar, NTD) versus the host country's currency, in which nominal exchange rates are deflated with the prices of the respective countries to control for possible movements in prices following the change in nominal exchange rates. In addition, since it is time-consuming to make an FDI decision, the final decision might be more closely related to the previous exchange levels, and thus the one-period lagged values are used. The expected sign of this variable is negative.

$S_{i,t-1}$: the one-period lagged real exchange rate of Taiwan's currency (New Taiwan Dollar, NTD) versus the third country's currency. The expected sign of this variable is positive.

$\mu_{R,it}$: the trend of the real exchange rates R. The expected sign of this variable is negative.

$\mu_{S,it}$: the trend of the real exchange rates S. The expected sign of this variable is positive.

ρ_{it}: the correlation between the real exchange rates *R* and *S*. The expected sign of this variable is positive.

$\sigma_{R,it}$: the volatility of the real exchange rate *R*. The expected sign of this variable is ambiguous a priori. To test the validity of our theory, we define a dummy variable, D_R, whose value is 1 for $\rho_{it} > \sigma_{R,it}/\sigma_{S,it}$, and 0 otherwise. According to Proposition 2, the expected sign of (β_5+β_8) is positive, and that of (β_5) is negative.

$\sigma_{S,it}$: the volatility of the real exchange rate *S*. The expected sign of this variable is also ambiguous a priori. We define a dummy variable, D_S, whose value is 1 for $\rho_{it} > \sigma_{S,it}/\sigma_{R,it}$, and 0 otherwise. According to Proposition 3, the expected sign of (β_6+β_9) is positive, and that of (β_6) is negative.

$W_{2,it}/W_{3,it}$: the ratio of the host country's real wage rate over the third country's real wage rate. The expected sign of this variable is negative.

DCH_{it}: during our sample period, Taiwan's government required firms to register their investments in China if they did not do so prior to their investments in previous years. As a result, the official numbers of new FDI cases in several years are biased upward. A dummy variable is used to control for this bias, whose value is 1 for the years 1993, 1997, 1998, 2002, and 2003, and 0 for the other years.

$D78_{it}$: a dummy variable is used to control for the effect of the Asia financial crisis in 1997 and 1998, whose value is 1 for the years 1997 and 1998, and 0 for the other years.

4. Data and empirical results

Data

Taiwan's outward FDI has increased sharply since the 1990s. As shown in Table 2, China is the most popular destination of Taiwan's overseas investments, accounting for more than 50% of its total outward FDI. Table 3 reveals that the cases of cost savings make up the most important investing motives of Taiwan's FDI, particularly for investment into China and Southeast Asian countries. Since China and Southeast Asian countries together account for more than 65% of Taiwan's outward FDI and cost savings are the most important motivation, our sample composes of Taiwan's outward FDI toward these countries.

This paper employs country panel data on Taiwan's outward FDI toward low-wage countries to test our theory. This dataset consists of 6 countries - China, Indonesia, Malaysia, Philippines, Thailand, and Vietnam - over the period 1985 to 2006. There are 122 observations in total. Our dataset is an unbalanced panel. The observations between 1985 and 1990 about investment into China are not included in the sample because Taiwan's government prohibited its firms to invest into China during that period. In addition, the observations between 1985 and 1988 for Vietnam are not included in the sample either because of the huge movements in Vietnam's exchange rate during that period.

The amount of FDI flows used in this study is the approved amount of Taiwan's outward FDI. The real exchange rates are converted into indices with 2000 as the base year. Regarding the third country's real exchange rates (S), we use the ratio of Taiwan's outward FDI in the respective country as its weight to calculate a weighted average real exchange rate. The sources of the data are described in the Appendix.

The literature proposes several measures of trend, volatility, and correlation of real exchange rates. Following Tsay (2002, p.229), we first use a modified average, a modified standard deviation, and a modified correlation of the monthly changes in the logarithm of

the real exchange rates to respectively stand for the trend, volatility, and correlation of real exchange rates, which are designed to approximate a continuous-time geometric Brownian motion process. We then use a Multivariate GARCH (MGARCH) process to estimate the conditional mean, variance, and correlation of the real exchange rates as the other measures of its trend, volatility, and correlation, since some studies such as Pozo (1992) note that exchange rates often exhibit persistent behavior.[5]

After calculating the variance of the exchange rates, we finally derive the dummies D_R and D_S according to the definitions illustrated in Propositions 2 and 3. We obtain 26 observations representing the high correlation period for the host country, whereas we also obtain 25 observations representing the high correlation period for the third countries. Table 4 reports the summary statistics of these variables.

Empirical results

Table 5 shows the estimation results of our empirical model, and four regression equations are estimated. The result in Column 1 uses Tsay's (2002) measures of the trend, volatility, and correlation of real exchange rates, while the result in Column 2 uses the measures from a MGARCH model. The adjusted R squared indicates a very high goodness of fit. Moreover, most explanatory variables have the expected signs and are statistically significant. However, some empirical results are sensitive to the measures of the trend and volatility of exchange rates.

The empirical results illustrate that the exchange rate level and its trend and volatility have an important impact on the determination of FDI. In particular, there indeed exist third country effects. This reveals that an appreciation of the host country's currency will deter FDI activity, while an appreciation of the exchange rates of the third countries will stimulate it. In addition, an expected appreciation of the host country's exchange rate and

[5] See Appendix for the derivation of the measures of the trend, volatility, and correlation of real exchange rates.

the third countries' exchange rates has a similar effect. These results are consistent with the prediction of our theoretical model.

As for the impact of volatility of exchange rates, the results indicate that it is important to consider the correlation between exchange rates, which is positively related to FDI activity and which is supportive of Proposition 1. Moreover, an increase in the volatility of the host country's exchange rates will stimulate FDI activity if the correlation of the exchange rates is high enough, which is consistent with the prediction of Proposition 2. This indicates that it is essential to take into account the correlation effects when analyzing the relationship between exchange rate volatilities and FDI across countries. However, although the impact of the volatility of third countries' exchange rates is found to be positive when the correlation of the exchange rates is high enough, which is consistent with the prediction of Proposition 3, the estimates are not statistically significant.

Finally, the real wage rates of the host country relative to the third countries are found to be negatively related to FDI activity, which is consistent with Propositions 6 and 7. The impact of the Asian financial crisis is also found to be negative with Taiwan's FDI.

5. Conclusion

This paper applies a real options model to examine the impact of exchange rate movements on FDI activity both theoretically and empirically. In contrast to previous studies, the effects of exchange rate changes in the host country as well as third countries are analyzed. It is shown that while the depreciation of the host country's currency stimulates cost-saving FDI activity, the depreciation of the third country's currency deters it. In addition, exchange rate uncertainty in the host country and third countries may have a positive impact on FDI activity if the correlation between these countries' currencies is

high enough. Finally, the real wage rates of the host country relative to those of the third countries are negatively related to FDI activity.

The panel data on Taiwan's outward FDI in China and Southeast Asian countries over the period 1985-2006 are employed to test the validity of the theoretical results. The empirical findings indicate that the exchange rate level, its trend and correlation, and the relative wage rates between the host countries and the third countries have had a significant impact on Taiwanese firms' outward FDI. Moreover, the empirical results are generally consistent with the prediction of the theory. These results suggest that there indeed exist third country effects of exchange rate movements on FDI activity.

Appendix Data Description

The annual approved amount of Taiwan's outward FDI over the period 1985-2006 is collected from "*Statistics on Overseas Chinese & Foreign Investment, Technical Cooperation, Outward Investment, Outward Technical Cooperation*," Investment Commission, Ministry of Economic Affairs (MOEAIC), ROC, 2007. GDP and CPI data are compiled from the website of International Monetary Fund (http://www.imf.org/external/data.htm). The nominal exchange rates are compiled from the Central Bank of the Republic of China (Taiwan) and the wage rates are collected from the website of International Labor Organization (http://www.ilo.org/stat/index.htm).

Two alternative measures of trend and volatility of the real exchange rates are used. First, μ and σ are defined respectively as a modified average and a modified standard deviation of the monthly changes in the log of the real exchange rates over the past 24 months - that is:

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

where $r_j = \log m_j - \log m_{j-1}$; $T = 24$; $m = \{R, S\}$; Δ is the space time interval, equal to $1/T$.

Second, a multivariate GARCH (MGARCH) process is adopted to estimate the volatility. With data covering the period from 1984:01 to 2006:12, we conduct the Augmented Dickey Fuller (ADF) test. The test result rejects the null hypothesis of unit root for $\Delta \ln m_t$. The estimated MGARCH model is as follows:

$$\Delta \ln m_t = \ln m_t - \ln m_{t-1} = \theta_m + u_{m,t},$$

$$h_{R,t} = c_1 + a_1 u_{R,t-1}^2 + b_1 h_{R,t-1},$$

$$h_{S,t} = c_2 + a_2 u_{S,t-1}^2 + b_2 h_{S,t-1},$$

$$h_{R,S,t} = c_3 + a_3 u_{R,t-1} u_{S,t-1} + b_3 h_{R,S,t-1},$$

where $\Delta \ln m_t$ is the first difference of the real exchange rates, and h_t is the conditional variance of the error term u_t. Thus, μ, σ, and ρ are defined respectively as:

$$\sigma_{m,t} = \left[\frac{1}{T} \sum_{j=1}^{T} h_{m,t-j+1} \right]^{1/2}, \quad \mu_{m,t} = \frac{1}{T} \sum_{j=1}^{T} u_{m,t-j+1}, \text{ and } \quad \rho_t = \frac{1}{T} \sum_{j=1}^{T} h_{R,S,t-j+1} \Big/ \left(h_{R,t-j+1} h_{S,t-j+1} \right)^{1/2}.$$

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Table 1. Expected signs of the determinants of FDI

Variables / Types	Exchange Rate Volatility (σ_R)	Exchange Rate Volatility (σ_S)	Exchange Rate Correlation (ρ)	Exchange Rate Level (R)	Exchange Rate Level (S)	Exchange Rate Trend (μ_R)	Exchange Rate Trend (μ_S)	Sunk Costs (k)	W_2	W_3
$\rho > \sigma_R/\sigma_S$	+		+	–	+	?	+	–	–	+
$\rho < \sigma_R/\sigma_S$	–		+	–	+	?	+	–	–	+
$\rho > \sigma_S/\sigma_R$		+	+	–	+	?	+	–	–	+
$\rho < \sigma_S/\sigma_R$		–	+	–	+	?	+	–	–	+

Table 2. Outward FDI of Taiwan by destination

Unit: million USD

Year	China		Southeast Asia		Others		Total
	Amounts	%	Amounts	%	Amounts	%	Amounts
1952~1995	6,349	39.9	3,182	20.0	6,368	40.1	15,899
1996	1,299	38.3	587	17.3	1,509	44.4	3,395
1997	4,549	62.9	641	8.9	2,038	28.2	7,228
1998	2,103	39.4	477	9.0	2,750	51.6	5,331
1999	1,374	30.4	522	11.5	2,625	58.1	4,522
2000	2,718	35.4	389	5.1	4,577	59.6	7,684
2001	2,880	40.1	523	7.3	3,772	52.6	7,176
2002	6,932	68.7	211	2.1	2,950	29.2	10,093
2003	8,340	71.5	298	2.6	3,029	26.0	11,667
2004	6,941	67.2	966	9.4	2,416	23.4	10,323
2005	6,007	71.1	264	3.1	2,183	25.8	8,454
2006	7,642	63.9	1,065	8.9	3,250	27.2	11,958
2007	9,962	60.6	2,094	12.7	4,375	26.6	16,432
Total	67,095	55.8	11,222	9.3	41,844	34.8	120,161

Source: Investment Commission, Ministry of Economic Affairs, ROC. 2008 *Statistics on Overseas Chinese & Foreign Investment, Technical Cooperation, Outward Investment, Outward Technical Cooperation*.

Table 3. The motives of Taiwan's outward FDI by country

Unit: %

Country	2004			2005			2006		
	Obs	Cost	Market	Obs	Cost	Market	Obs	Cost	Market
China	730	73.97	55.21	644	80.43	65.68	694	74.78	64.12
Malaysia	12	58.33	41.67	10	60.00	40.00	9	66.67	33.33
Thailand	11	63.64	36.36	10	80.00	50.00	16	68.75	18.75
Indonesia	12	83.33	33.33	13	84.62	46.15	10	90.00	30.00
Philippines	12	50.00	41.67	9	66.67	33.33	5	60.00	40.00
Vietnam	36	91.67	41.67	28	96.43	53.57	28	75.00	39.29
U.S.	164	4.88	41.46	89	3.37	35.96	100	7.00	34.00
Europe	21	-	52.38	18	5.56	50.00	80	68.75	13.75
Hong Kong	37	18.92	24.32	24	33.33	58.33	49	36.73	20.41
Japan	31	-	32.26	14	-	28.57	25	12.00	32.00

Source: Investment Commission, Ministry of Economic Affairs, ROC. 2004-2006. *Survey on Taiwanese Firms in Mainland China*.

Notes: Obs: observation; Cost: reducing production cost; Market: searching new market.

Table 4. Summary statistics

	Mean	Min	Max	Standard deviation
FDI (million USD)	495.3	0.0000	7,699	1,496
Real exchange rate R (index)	115.7	47.47	279.0	28.22
Real exchange rate S (index)	111.0	81.93	279.0	25.10
Real exchange rate correlation ρ (MGARCH)	0.4374	-0.0110	0.9570	0.2174
Real exchange rate correlation ρ (Tsay)	0.4639	-0.3868	0.9686	0.3061
Real relative wage rate W_2/W_3	1.2127	0.1083	3.9020	1.0315

Table 5. Estimation results of the determinants of Taiwan's cost-oriented outward foreign direct investment

Model / Explanatory Variable	Model 1	Model 2
Intercept	0.312 (0.14)	1.450 (0.65)
R_{t-1} (β_1)	-0.015 (-1.11)	-0.025[b] (-2.03)
S_{t-1} (β_2)	0.033[b] (2.62)	0.030[b] (2.37)
μ_R (β_3)	-9.138[a] (-3.94)	-187.8[a] (-3.72)
μ_S (β_4)	5.119[b] (2.12)	177.3[a] (3.48)
σ_R (β_5)	-3.418 (-0.75)	-10.19 (-1.30)
σ_S (β_6)	-2.578 (-0.57)	15.95 (0.92)
ρ (β_7)	1.063[b] (2.45)	0.798 (0.82)
$\sigma_R * D_R$ (β_8)	22.90[a] (4.53)	33.58[a] (6.75)
$\sigma_S * D_S$ (β_9)	3.568 (0.92)	3.902 (0.68)
W_2/W_3 (β_{10})	-0.659[c] (-1.79)	-0.092 (-0.24)
DCH (β_{11})	2.064[a] (14.6)	2.220[a] (15.7)
D78 (β_{12})	-0.116 (-0.35)	-0.530[c] (-1.83)
$\beta_5+\beta_8$	19.48[b] (2.56)	23.40[b] (2.40)
$\beta_6+\beta_9$	0.991 (0.17)	19.85 (1.05)
Adjusted R-squared	0.9881	0.9884

Notes: 1. Models 1 and 2, respectively, use Tsay's (2002) and MGARCH (1,1) measures of trend and volatility of real exchange rates. 2. Five country dummies are included in the regression equations, but their coefficients are not reported here. 3. The t-statistics are in parentheses; subscripts a, b, and c denote that the test statistics are significant at the 1%, 5% and 10% confidence levels, respectively.