The Impact of Exchange Rate Movements on Foreign Direct Investment: Market-oriented versus Cost-oriented

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Abstract

This paper examines the impact of exchange rate movements on foreign direct investment (FDI). We first employ a real options model to show that while the depreciation of a host country's currency tends to stimulate FDI activity of cost-oriented firms, the depreciation tends to deter FDI activity for market-oriented firms. With industry panel data on Taiwan's outward FDI into China over the period 1991-2002, our empirical findings indicate that the exchange rate level and its volatility in addition to the relative wage rate have had a significant impact on Taiwanese firms' outward FDI into China. In general, the empirical results are consistent with the prediction of the theory. Our results reveal that the relationship between exchange rates and FDI is crucially dependent on the motives of investing firms. Without considering this fact in an empirical model, the testing results might suffer from aggregations bias.

Keywords: FDI, exchange rate movements, real options approach

JEL Classification: F21, F31, G13

1. Introduction

The flows of foreign direct investment (FDI) have been increasing dramatically around the world since the 1970s. However, the level of FDI tends to fluctuate sharply over time - a phenomenon that cannot be explained satisfactorily by traditional theories. The rise in FDI is regarded by traditional theories as being motivated by the differences in the costs of domestic versus foreign production or the internalization of transaction costs involved in exporting or licensing a product to another country. While the traditional theories may explain the FDI level's increase in the long run, they offer little explanation for its substantial short-run movements.[1]

Ever since the breakdown of the Bretton Woods system in 1973, the exchange rates of many countries have been fluctuating considerably over time. A popular claim in the international business community is that exchange rates are one of the most important factors in a firm's FDI decision, because a devaluation of a country's currency can give foreigners an edge in buying the country's assets. Given the inadequacy of the traditional theories, a lot of work recently has been done in the area of exchange rate movements and FDI, but there is still no consensus either in theory or empirical studies.

Kohlhagen (1977) and Cushman (1985) show that foreign currency depreciation lowers the foreign production cost and thus stimulates FDI. Froot and Stein (1991) develop a model with an imperfect capital market and show that a depreciation of the domestic currency, by systematically lowering the relative wealth of domestic agents, can lead to foreign acquisition. Empirical evidence in a number of studies reveals that the appreciation of the home currency against the host currency encourages FDI, which are consistent with the prediction of the above-mentioned theories (Kohlhagen (1977), Cushman (1985), Froot and Stein (1991), Klein and Rosengren (1994), Blonigen (1997)).

Using Dixit's (1989b) real options framework, Campa (1993) by contrast shows that if a firm sets up a foreign subsidiary in order to sell a product which is produced in the home country, then the appreciation of the host country's currency will generate higher revenue, thus stimulating FDI. Empirical evidence from the wholesale and chemicals industries in the United States in Campa (1993), Bell and Campa (1997)

[1] Blonigen (1997, p. 447) argues that it is difficult for these traditional theories to explain why foreign direct investment can double in one year during a certain period.

and Tomlin (2000) is consistent with this hypothesis. However, Campa and Goldberg (1995) find that the directions of the effects of the exchange rate on FDI are different across industries. Using the data on FDI among the United States and 12 developed countries, Gorg and Wakelin (2002) show that U.S. outward FDI is positively correlated with an appreciation in the host country currency while U.S. inward FDI is negatively correlated with an appreciation in the dollar.

As correctly pointed out by Carruth, Dickerson and Henley (2000), one possible reason for the mixed results in the previous studies is that the impacts of exchange rate changes on FDI are different across industries and an analysis based on aggregate data might result in aggregation bias. To illustrate the importance in considering the diversity in investing firms' motives, the purpose of this paper investigates the effects of changes in the exchange rate on market-oriented FDI versus cost-oriented FDI both theoretically and empirically.

We first apply Dixit's (1989b) real options model to compare the differences in the effects of exchange rate movements on the FDI activity of market-oriented firms versus cost-oriented firms. It is shown that an appreciation of host country's currency will stimulate the FDI of market-oriented firms, but deter that of cost-oriented firms. The industry panel data on Taiwan's outward FDI in China over the period 1991-2002 are then employed to test the validity of the theoretical results, since Chen (1992) and Chen and Yang (1999) reveal that the outward FDI activity of some Taiwanese firms has been market-oriented, whereas that of some other firms has been cost-oriented. In addition, despite the popular claim that the appreciation of Taiwan's currency has been one of the most important reasons for the drastic rise of Taiwanese outward FDI, the role of the exchange rate has not been considered in recent studies (e.g. Chen (1992), Chen (1996), Chen and Yang (1999), Henly et al. (1999), and Zhang (2001)). This paper will fill these gaps in the literature.

The remainder of the paper proceeds as follows. In the following section, Dixit's (1989b) model is presented and the effects of exchange rate movements on the FDI activity of market-oriented firms versus cost-oriented firms are illustrated. 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 FDI and the exchange rate

An orthodox investment theory, the net present value (NPV) theory, assumes that investment decision is to be taken now or never. This theory ignores the option of delaying an investment. Given the inadequacy of such an orthodox investment theory, since the 1980s, a real options theory has been developed to analyze investment behavior. The real options theory emphasizes three important characteristics of investment. First, investment is at least partially irreversible, implying that some investment costs cannot be completely recovered by selling capital. Second, investment decisions have to be made in an uncertain world. Third, it is possible to delay the investment decision in order to obtain more information about the future.

Investment spending is like a financial call option and its exercise price is the sunk costs involved in the investment. The return of executing the investment is the expected present discounted value of future profits. The call option's value is the value of the option for waiting and entering the market in the future. FDI decisions are made in a more uncertain environment than in a domestic investment; especially, if the firm faces a larger exchange rate risk. Furthermore, FDI generally incurs substantial sunk costs.[2] Hence, a real options approach is more relevant for analyzing the determinants of the timing of FDI.

Following Dixit (1989b), a simple real options model is used to investigate the relationship between exchange rates and FDI. To illustrate the importance of the diversity of motives in investigating the determinants of FDI, we focus on two extreme cases according to the destination of its product - namely, market-oriented FDI versus cost-oriented FDI. It will be shown in the following that the effects of exchange rate on FDI are rather different under these two cases.

To begin with, we assume that a risk neutral MNE desires to invest abroad and its problem is deciding when to enter the foreign market. The objective of the MNE is assumed to be in obtaining maximum expected profits in terms of a home country's currency. The MNE faces a perfectly competitive good market. Next, it can produce a unit flow of output at variable costs, while locating its branch in the host country and investing a lump sum k, where k shows the sunk costs of the entry, which are assumed

[2] Laar (2000) illustrates several types of sunk costs for executing a foreign investment project: irreversible orientation costs, such as the cost of the country specific literature and seminars during the decision making process; irreversible set-up costs, such as infrastructure investments; and recurrent fixed costs, such as the rent or depreciation of the building and machinery.

to be expressed in the home currency[3]. For simplicity, we assume that the variable costs comprise labor costs only and the input-output coefficients are fixed. Therefore, the variable costs can be treated as the wage rate.

Suppose that exchange rate, R, expressed in units of home currency per foreign currency, follows an exogenously geometric Brownian motion[4]

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

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

Market-oriented firm

Market-oriented FDI refers to the situation in which a firm sets up a foreign subsidiary to produce and sell in a given foreign market. It is assumed that the firm remits the profits of the subsidiary back to its home country. Hence, its profit flows, π_M, per period are

$$\pi_M\left(R\right) = P_f R - W_f R .$$

where P_f is the foreign market price and W_f is the foreign wage rate. These two variables are expressed in foreign currency.

Because we focus on the timing of entry, we assume a potential entrant stays in the market forever after entering the market.[5] The firm faces a binary decision problem each period as follows:

$$V_0\left(R\right) = \max\left\{\xi_M\left(R\right) - k, \frac{1}{1+\Delta t\rho}\mathrm{E}\left[V_0\left(R'\right)\middle| R\right]\right\}, \tag{2}$$

where V_0 is the optimal expected net present value; $\xi_M\left(R\right) = \left(P_f - W_f\right)R \big/ \left(\rho - \mu\right)$ represents the expected present value that stays in the market forever, ρ is the discount rate; Δt is the time interval; R' is the exchange rate in period t+1. The former term

[3] To simplify the following analysis, in this paper the sunk costs k are expressed in the home country's currency instead of foreign currencies, in contrast with Dixit (1989a) and other studies. Nevertheless, our results are not changed if the sunk costs are expressed in foreign currencies. This is because the initial exchange rate is exogenous and thus does not influence the firm's value of the option to wait.

[4] The subscript t of R is suppressed in this section for simplicity.

[5] The following results are not changed if we allow the firm to have an option to exit after it enters the market.

on the right-hand side, $\xi_M(R)-k$, is the net entry value and the latter term, $\left[1/(1+\Delta t\rho)\right]\mathrm{E}\left[V_0(R')\middle|R\right]$, is the value of the option to wait.

Since the profit function in this model is an increasing function in *R*, there is a cutoff point, R_H, at which if $R>R_H$, then the entry value $\xi_M(R)$ minus entry cost *k* is greater than the value of the option to wait, and thus the firm's optimal decision is to enter the market.[6] In other words, the lower the value of R_H is, the higher the probability will be for the firm to enter the market. Using value-matching and smooth-pasting conditions, we have

$$R_H=\frac{k(\rho-\mu)}{P_f-W_f}\frac{\beta}{\beta-1}, \tag{3}$$

where $\beta=\sigma^{-2}\left[-\left(\mu-0.5\sigma^2\right)+\sqrt{\left(\mu-0.5\sigma^2\right)^2+2\sigma^2\rho}\right]$. From Equation (3), it can be shown that[7]

$$\frac{dR_H}{dk}>0,\ \frac{dR_H}{dW_f}>0,\ \frac{dR_H}{d\sigma}>0,\ \frac{dR_H}{d\mu}<0. \tag{4}$$

Cost-oriented firm

Cost-oriented FDI refers to the situation in which a firm sets up a foreign subsidiary to produce and exports output back to the home country[8] or a third country. To simplify, we focus on the former case. It is assumed that the firm wholly exports output of its foreign subsidiary back to the home country. Thus, the profit flows, π_C, per period can be expressed as

$$\pi_C(R)=P_d-W_fR,$$

where P_d is the domestic market price in domestic currency.

According to the profit flows, it is obvious that the cost-oriented firm benefits

[6] See Dixit and Pindyck (1994), p.128.
[7] See Appendix 1 for the derivation.
[8] This phenomenon is referred to as "reverse imports" in the literature. Liu and Lin (2002) find that the reverse imports of Taiwanese multinational firms in the electronics & electric appliances, metal products and textile industries account for more than 30% of total revenue in their foreign subsidiaries.

from a depreciation of the foreign currency. Therefore, there is an entry threshold rate R_L at which a potential entrant enters if $R < R_L$. In other words, the higher the value of R_L is, the higher the incentive will be for the firm to enter the market. Let $\xi_C(R) = P_d/\rho - W_f R/(\rho-\mu)$ denote the expected present value of the cost-oriented firm that stays in the market forever. The firm faces a binary decision problem each period as follows.

$$V_0(R) = \max\left\{\xi_C(R) - k, \frac{1}{1+\Delta t\rho}\mathrm{E}\left[V_0(R')\middle|R\right]\right\}. \tag{5}$$

Using value-matching and smooth-pasting conditions, we have

$$R_L = \left(\frac{P_d}{\rho} - k\right)\frac{(\rho-\mu)\cdot\alpha}{W_f\cdot(\alpha+1)}, \tag{6}$$

where $\alpha = \sigma^{-2}\left[\left(\mu - 0.5\sigma^2\right) + \sqrt{\left(\mu-0.5\sigma^2\right)^2 + 2\sigma^2\rho}\right]$. From Equation (6), it can be shown that[9]

$$\frac{dR_L}{dk} < 0, \frac{dR_L}{dW_f} < 0, \frac{dR_L}{d\sigma} < 0, \frac{dR_L}{d\mu} < 0. \tag{7}$$

Determinants of FDI

From Equations (4) and (7), we can determine the expected signs of these determinants of FDI, which are summarized in Table 1. These results reveal that the effects of these determinants on FDI for these two types of firms have similarities as well as differences.

First, we find that the expected sign of the volatility of the real exchange rate is negative, which is the same for the two types of firms. The economic intuition is that the investment is like a call option whose value increases if the underlying uncertainty increases. Hence, the potential entrant has more incentive to wait until it gets extra information from the market as the uncertainty rises.

Second, the expected sign of the sunk costs k is negative, which is also the same for the two types of firms. This is because, given the irreversibility of investment, the higher the entry costs are, the higher the revenues or the lower the variable costs will

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[9] Ibid.

be that are requested to compensate the opportunity loss. Thus, the higher the entry trigger rate will be for the market-oriented firms and the lower the entry trigger rate will be for the cost-oriented firms. As a result, the amount of FDI should decrease with the increase in *k*. It is worth noting that, if sunk investment costs are zero, then the volatility would have no effect on the entry decision[10]. This is because the firm could decide whether or not to abandon the project at each moment of time without any opportunity costs. Consequently, the uncertainty is independent of the amount of FDI.

Third, the expected signs of the wage rate are also the same for these two types of firms. The higher the foreign wage rate is, the higher the variable costs will be that are involved in foreign production. Therefore, a cost-oriented firm or a market-oriented firm is less willing to set up a foreign subsidiary for production activity.

Finally, the effects of the exchange rate level and its trend differ between two different types of firms. As for market-oriented firms, they benefits from an appreciation of foreign currency because their profits in terms of the home currency are higher (if $P_f > W_f$). However, for cost-oriented firms, an appreciation of the foreign currency implies higher variable costs in terms of the home currency without affecting revenue. As a result, the profits of a foreign subsidiary will be lower. Therefore, the expected sign of the exchange rate for market-oriented firms is positive, whereas the expected sign of the exchange rate for cost-oriented firms is negative. As for the effects of the exchange rate trend, because it represents the expected future exchange rate level, the expected signs of μ for market-oriented firms are positive whereas the expected signs for cost-oriented firms are negative, based on the similar reasoning as mentioned above.

＜＜Table 1＞＞

3. Empirical model

Based on the theoretical framework of this paper, the following empirical model is established:

10 It is that much obvious that we omit the derivations.

$$
\begin{aligned}
FDI_{i,t}^{*} = {} & \alpha_i + \beta_1 R_{t-1} + \beta_2 \mu_t + \beta_3 \sigma_t + \beta_4 Wage_{i,t-1} + \beta_5 Sunk_i * \sigma_t \\
& + \beta_6 Market_i * R_{t-1} + \beta_7 Cost_i * R_{t-1} \\
& + \beta_8 Market_i * \mu_t + \beta_9 Cost_i * \mu_t \\
& + \beta_{10} Trend_t + \beta_{11} D_t + \varepsilon_{it}^{*}
\end{aligned} \tag{8}
$$

Here, subscript i refers to industries, subscript t refers to time periods, α_i and β_j $(j = 1,...11)$ are parameters, and ε_{it}^{*}'s are disturbance terms. The definitions of the variables in Equation (8) are explained as follows:

$FDI_{i,t}^{*}$: the desired number of new FDI cases of industry i at time t, which is divided by China's real GDP to control for changes in the size of the host country.

R_{t-1}: the one-period lagged real exchange rate of Taiwan's currency (New Taiwan Dollar, NTD) versus China's currency (Renminbi, RMB) , in which nominal exchange rates are deflated with the prices of the respective countries to control for the 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 related to the previous exchange level, and thus the one-period lagged values are used. The expected sign of this variable is positive for market-oriented firms, negative for cost-oriented firms.

μ_t: the trend of the real exchange rates. The expected sign of this variable is positive for market-oriented firms, negative for cost-oriented firms.

σ_t: the volatility of the real exchange rate. The expected sign of this variable is zero for those industries without sunk investment costs, and negative for those industries with sunk investment costs.

$Wage_{i,t-1}$: the ratio of China's one-period lagged real wage rate over Taiwan's one-period lagged real wage rate. One alternative for investing firms to produce abroad is to produce in the home country instead. To control for this option, the relative wage rates instead of the absolute wage rates are used in our empirical model. The expected sign of this variable is negative.

$Sunk_i$: a dummy variable, whose value is 1 for industries with substantial sunk investment costs and 0 for other industries.

Market$_i$: a dummy variable, whose value is 1 for market-oriented industries and 0 for other industries.

Cost$_i$: a dummy variable, whose value is 1 for cost-oriented industries and 0 for other industries.

Trend$_t$: a time trend, used to control for other time-related variables.

D_t: during our sample period, Taiwan's government required firms to register their investment in China if they did not do so prior to their investment 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 of 1993, 1997, 1998, and 2002, and 0 for the other years.

Since we have only the observations regarding the numbers of new FDI cases in different industries, the dependent variable is limited to be non-negative; that is,

$$FDI_{i,t} = \begin{cases} FDI^*_{i,t}\ , & \text{if } FDI^*_{i,t} > 0 \\ 0 \ , & \text{if } FDI^*_{i,t} \leq 0 \end{cases} \tag{8}$$

where $FDI_{i,t}$ shows the observed new FDI cases. As the dependent variable's range is constrained, a Quasi Maximum Likelihood Tobit Model is adopted to fit the data.[11]

4. The data and empirical results

The Data

Industry panel data on Taiwan's outward FDI in China are employed to test our theory. This dataset consists of 27 sectors over the period from 1991 to 2002 with a total sample size of 324 observations. The sources of the data are described in Appendix 2.

The numbers of new FDI cases used in this study are the approved cases of Taiwan's outward FDI in China, which vary across industries and over time. The exchange rates between NTD and RMB are calculated from the ratio of exchange rates of NTD and US Dollar (USD), and the exchange rates of RMB and USD.

Several measures of trend and volatility of the real exchange rate have been

[11] See Hsiao (2003), Ch.8.

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 real exchange rate, 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.[12]

In regards to the sunk investment costs dummy, $Sunk_i$, its value is 1 for an industry which is among the top ten industries by the percentage of Taiwanese subsidiaries with R&D departments as well as among the top ten industries by the percentage of Taiwanese subsidiaries with marketing departments in China during 1999-2002; 0 otherwise. According to these criteria, the industries with high sunk investment costs in our sample include food & beverage processing, chemicals, non-metallic minerals, machinery equipment, and precision instruments.[13]

The market-oriented industry dummy, $Market_i$, is defined as follows: If the percentage of an industry's sales in China in its total revenue is significantly greater than the weighted-average percentage of all industries at the 5% significant level, then the industry is referred to as market-oriented and the value of $Market_i$ is 1; 0 otherwise. Market-oriented industries in our sample include mining, construction instrument, restaurant, transportation, and storage.

The cost-oriented industry dummy, $Cost_i$, is defined similarly as follows: If the percentage of reverse-imports of an industry from China in its total sales is significantly greater than the weighted-average percentage of all industries at the 5% significant level, then it is referred to as cost-oriented and the value of $Cost_i$ is 1; 0 otherwise. It turns out that the cost-oriented industries in our sample are electronics & electric appliances and plastic products.

4. Empirical results

Table 2 summarizes the results of the Tobit estimation of our empirical model. Six regression equations are estimated. In the first three equations shown in Columns 1, 2 and 3, Tsay's (2002) measures of the trend and volatility of real exchanger rates are

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[12] See Appendix 2 for the derivation of the measures of the trend and volatility of real exchange rates.

[13] Our empirical results are basically the same when we use top five industries instead of top ten industries.

used while the measures estimated from a GARCH model are adopted in the other equations reported in Columns 4, 5 and 6.

＜＜Table 2＞＞

Column 1 is our benchmark case in which the sunk costs dummy and industry dummies that control for investing motives are not considered. The results in Column 1 indicate that the coefficients of all the explanatory variables have a negative sign and are significant at the 5% level. These results reveal that overall the uncertainty in the exchange rate of RMB has had a negative impact while a depreciation of RMB and low relative wage rates in China have had a positive impact on Taiwanese firms' investment into China.

Column 2 attempts to test the relationship between sunk cost and the effect of exchange rate uncertainty. It indicates that both the coefficient of σ_t and that of $Sunk_i*\sigma_t$ are negative, but only the latter is statistically significant at the 5% level. These results suggest that exchange rate volatility would exert a significantly negative impact on FDI activity of the Taiwanese industries only if those industries face considerable sunk investment costs, which is consistent with the prediction of our theoretical framework.

The estimation in Column 3 is used to test the differences in the impact of real exchange rates on market-oriented FDI versus cost-oriented FDI. All explanatory variables have the expected signs. The coefficients of $Market_i*R_{t-1}$ and $Market_i*\mu_t$ are significantly positive, whereas those of $Cost_i*\ R_{t-1}$ and $Cost_i*\mu_t$ are significantly negative. These results imply that the NTD's appreciation will stimulate FDI activity for cost-oriented firms, but deter that of market-oriented firms. Furthermore, Wald test statistics in the same column indicate that the null hypothesis - the coefficients of $Market_i*R_{t-1}$ and $Cost_i*\ R_{t-1}$ are equal, or the null hypothesis - the coefficients of $Market_i*\mu_t$ and $Cost_i*\mu_t$ are equal, is rejected at the 5% level. It demonstrates that the effects of the real exchange rate on FDI indeed vary with its motives, as proposed in this paper. In addition, the results in Columns 4, 5, and 6 show that the empirical results in Columns 1, 2, and 3 are not qualitatively sensitive to different measures of the trend and volatility of real exchange rates.

To sum up, our empirical findings indicate that relative wage rates, the exchange rate level and its volatility have had a significant impact on Taiwanese firms' outward FDI into China. In particular, our results reveal that China's low relative wage rates have been one of the important driving forces behind Taiwanese investment into China. Moreover, exchange rate uncertainty has had a negative impact on Taiwanese firms' FDI, particularly for those firms facing considerable sunk investment costs. Finally, the relationship between exchange rates and FDI vary 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 changes influence FDI activity. The real options framework of Dixit (1989b) is used to compare the effects of exchange rate changes on the FDI decision of market-oriented firms versus cost-oriented firms. We show that, given the irreversibility of investment, exchange rate uncertainty has a negative impact on a firm's outward FDI regardless of whether the firm is market-oriented or cost-oriented. In addition, while the depreciation of a host country's currency tends to stimulate the outward FDI activity of cost-oriented firms, it does tend to deter the outward FDI activity of market-oriented firms.

The industry panel data on Taiwan's outward FDI in China over the period 1991-2002 are employed to test the validity of the theoretical results. The empirical findings indicate that the exchange rate level and its volatility have had a significant impact on Taiwanese firms' outward FDI into China. In general, the empirical results are consistent with the prediction of the theory. Our results reveal that the relationship between exchange rates and FDI is crucially dependent on the motives of the investing firms. Without considering this fact in an empirical model, the testing results might suffer from aggregations bias.

Appendix 1 The Derivation of Equations (4) and (7)

This appendix describes the derivation of equations (4) and (7) in Section 2 of the main text. The derivation of $\partial R_H/\partial k$, $\partial R_H/\partial W_f$, $\partial R_L/\partial k$ and $\partial R_L/\partial W_f$ is that much obvious that we omit the proof. To save space, we use the following results in Dixit (1989b, p.626):

$$\beta = \frac{-(\mu-0.5\sigma^2)+\sqrt{(\mu-0.5\sigma^2)^2+2\sigma^2\rho}}{\sigma^2} > 1, \tag{A1}$$

and

$$\alpha = \frac{(\mu-0.5\sigma^2)+\sqrt{(\mu-0.5\sigma^2)^2+2\sigma^2\rho}}{\sigma^2} > 0, \tag{A2}$$

and those in Dixit and Pindyck (1994, p.114):

$$\frac{\partial\beta}{\partial\sigma} = \frac{-2\mu^2+\mu\sigma^2-2\rho\sigma^2+2\mu\sqrt{2\rho\sigma^2+(\mu-0.5\sigma^2)^2}}{\sigma^3\sqrt{2\rho\sigma^2+(\mu-0.5\sigma^2)^2}} < 0, \tag{A3}$$

and

$$\frac{\partial\alpha}{\partial\sigma} = -\frac{2\mu^2-\mu\sigma^2+2\rho\sigma^2+2\mu\sqrt{2\rho\sigma^2+(\mu-0.5\sigma^2)^2}}{\sigma^3\sqrt{2\rho\sigma^2+(\mu-0.5\sigma^2)^2}} < 0. \tag{A4}$$

Using Equations (A1) ~ (A4), we have

$$\frac{\partial R_H}{\partial\sigma} = \frac{-R_H}{\beta(\beta-1)}\cdot\frac{\partial\beta}{\partial\sigma} > 0 \tag{A5}$$

and

$$\frac{\partial R_L}{\partial\sigma} = \frac{R_L}{\alpha(1+\alpha)}\cdot\frac{\partial\alpha}{\partial\sigma} < 0. \tag{A6}$$

According to Equation (3) in Section 2, differentiating R_H with respect to μ, we next have

$$\frac{\partial R_H}{\partial\mu} = \frac{R_H\cdot\phi}{(\beta-1)(\rho-\mu)\sqrt{2\rho\sigma^2+(\mu-0.5\sigma^2)^2}} \tag{A7}$$

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

Since we assume that $\mu<\rho$, the denominator of (A7) is positive. Note that $\partial\phi/\partial\mu = -\sigma(\partial\beta/\partial\sigma) > 0$. Hence, ϕ is a strictly increasing function of μ. Moreover, $\phi = 0$ when $\mu=\rho$, and thus we have $\phi<0$. Consequently, we have $\partial R_H/\partial\mu < 0$.

From Equation (6) in Section 2, differentiating R_L with respect to μ, we similarly have

$$\frac{\partial R_L}{\partial \mu} = \frac{R_L \cdot \psi}{(1+\alpha)(\rho-\mu)\sqrt{2\rho\sigma^2 + \left(\mu - 0.5\sigma^2\right)^2}} \tag{A8}$$

where $\psi = \rho - \mu - (1+\alpha)\sqrt{2\rho\sigma^2 + \left(\mu - 0.5\sigma^2\right)^2}$. It is obvious that the denominator of (A8) is positive. Since $0 < \rho$ and $\psi\big|_{\rho=0} = -2\,\mu^2/\sigma^2 < 0$, thus $\psi < 0$ if $\partial\psi/\partial\rho < 0$. Note that

$$\frac{\partial \psi}{\partial \rho} = \frac{-\mu - 0.5\sigma^2 - \sqrt{2\rho\sigma^2 + \left(\mu - 0.5\sigma^2\right)^2}}{\sqrt{2\rho\sigma^2 + \left(\mu - 0.5\sigma^2\right)^2}}. \tag{A9}$$

Because μ is the growth rate of the exchange rate, we have $\mu > -1$. Therefore, $\partial\psi/\partial\rho < 0$, if $\partial\psi/\partial\rho\big|_{\mu=-1} \le 0$ and $\partial^2\psi/\partial\mu\partial\rho < 0$. From Equation (A9), we have

$$\frac{\partial^2 \psi}{\partial \mu \partial \rho} = \frac{-\sigma^2\left(4\rho - 2\mu + \sigma^2\right)}{2\left[2\rho\sigma^2 + \left(\mu - 0.5\sigma^2\right)^2\right]^{3/2}} < 0,$$

and

$$\frac{\partial}{\partial \sigma^2}\left(\left.\frac{\partial \psi}{\partial \rho}\right|_{\mu=-1}\right) = \frac{-2 - \rho\left(2+\sigma^2\right) - \sigma^2}{2\sqrt{\left(1+\sigma^2 + 2\rho\sigma^2 + 0.25\sigma^4\right)^3}} < 0,$$

which implies that $\partial\psi/\partial\rho\big|_{\mu=-1}$ is a monotone function of σ^2. Moreover, $\partial\psi/\partial\rho\big|_{\mu=-1,\sigma^2=0} = 0$ and $\partial\psi/\partial\rho\big|_{\mu=-1,\sigma^2=\infty} = -2 < 0$, and thus $\partial\psi/\partial\rho\big|_{\mu=-1} \le 0$. We have now completed the proof of $\partial R_L/\partial\mu < 0$.

Appendix 2 Data Description

The annual approved cases of Taiwan's outward FDI in China, $FDI_{i,t}$, classified into 27 industries according to their CCC code and SIC code for the period of 1991 to 2002, are compiled from "*Statistics on Overseas Chinese & Foreign Investment, Technical Cooperation, Outward Investment, Outward Technical Cooperation*," Investment Commission, Ministry of Economic Affairs (MOEAIC), ROC, 2004. China's real GDP of China is measured at the price of 1995 in billions of RMB, which is compiled from the database of Taiwan Economic Journal (TEJ).

The level of the real exchange rate, R_t, is the average bilateral real exchange rate, expressed in units of NTD per RMB. It is calculated with a nominal exchange rate of NTD to USD, and that of RMB to USD, and it is deflated with Taiwan's CPI and China's CPI, respectively. The data are compiled from the AREMOS database, Ministry of Education, ROC (AREMOS).

The real relative wage index, $Wage_{i,t}$, defined as the ratio of the real annual average wage index of China over the real annual average wage index of Taiwan, is compiled from AREMOS. The base year is 2001, in which the value is 1.

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 form 1989:01 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:

$$\Delta \ln R_t = \ln R_t - \ln R_{t-1} = -\underset{(-1.35)}{0.0036} + u_t,$$

$$h_t = \underset{(5.12)}{0.0008} + \underset{(3.84)}{0.7156}\, u_{t-1}^2 - \underset{(-3.96)}{0.0560}\, h_{t-1},$$

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

$$\sigma_{GARCH,t} = \frac{1}{T}\sum_{j=1}^{T} h_{t-j+1}\ ,\ \mu_{GARCH,t} = \frac{1}{T}\sum_{j=1}^{T} u_{t-j+1}\ .$$

The monthly nominal exchange rates and CPI are compiled from the database of TEJ.

The data used to define sunk costs, market-oriented industries and cost-oriented industries are obtained from "*Survey on Taiwanese Firms in Mainland China*", 1999~2002, MOEAIC.

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Table 1 Expected signs of the determinants of FDI

Types \ Variables	Exchange Rate (R)	Exchange Rate Trend (μ)	Exchange Rate Volatility (σ)	Sunk Costs (k)	Host Country Wage Rate (W_f)
Market-oriented Firms	+	+	−*	−	−
Cost-oriented Firms	−	−	−*	−	−

* Without sunk costs, the expected sign of volatility is zero.

Table 2 Tobit estimation of the determinants of FDI

Explanatory variables \ Equations	Tsay (2002) (1)	Tsay (2002) (2)	Tsay (2002) (3)	GARCH (1,1) (4)	GARCH (1,1) (5)	GARCH (1,1) (6)
R_{t-1} (β_1)	-0.0059[a] (-8.66)	-0.0059[a] (-8.72)	-0.0061[a] (-8.91)	-0.0057[a] (-8.59)	-0.0056[a] (-8.61)	-0.0058[a] (-8.73)
μ_t(β_2)	-0.0085[a] (-6.73)	-0.0085[a] (-6.75)	-0.0091[a] (-7.12)	-0.1972[a] (-6.51)	-0.1962[a] (-6.51)	-0.2117[a] (-6.89)
σ_t(β_3)	-0.0072[b] (-2.30)	-0.0044[c] (-1.31)	-0.0043[c] (-1.32)	-1.0120[a] (-3.56)	-0.8409[b] (-1.83)	-0.8295[a] (-2.85)
$Wage_{i,t-1}$(β_4)	-0.0079[b] (-2.31)	-0.0076[b] (-2.26)	-0.0096[a] (-2.94)	-0.0064[b] (-1.89)	-0.0061[b] (-1.83)	-0.0080[a] (-2.46)
$Sunk_i*\sigma_t$ (β_5)		-0.0146[b] (-2.15)	-0.0147[b] (-2.25)		-0.8874[c] (-1.59)	-0.8870[c] (-1.64)
$Market_i* R_{t-1}$ (β_6)			0.0013[c] (1.36)			0.0012 (1.27)
$Cost_i* R_{t-1}$ (β_7)			-0.0027[b] (-1.94)			-0.0026[b] (-1.85)
$Market_i*\mu_t$(β_8)			0.0052[a] (2.57)			0.1252[a] (2.55)
$Cost_i*\mu_t$(β_9)			-0.0098[a] (-3.61)			-0.2165[a] (-3.29)
$Trend_t$	0.0009[a] (4.72)	0.0009[a] (4.70)	0.0010[a] (5.44)	0.0008[a] (3.89)	0.0008[a] (3.84)	0.0009[a] (4.52)
D_t	0.0045[a] (10.65)	0.0045[a] (10.74)	0.0045[a] (11.22)	0.0043[a] (10.14)	0.0044[a] (10.15)	0.0044[a] (10.62)
Wald test ($\beta_6 = \beta_7$)			6.50[a]			5.85[b]
Wald test ($\beta_8 = \beta_9$)			22.33[a]			19.68[a]
Likelihood ratio test	398.28[a]	399.62[a]	469.16[a]	398.71[a]	405.58[a]	469.36[a]

Notes: 1. Twenty-seven industry dummies are included in the regression equations, but their coefficients are not reported here. 2. Tsay (2002) and GARCH (1,1) represent two different measures of trend and volatility of real exchange rates. 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.