

Exchange Rate Movements and Foreign Direct
Investment: Evidence from Taiwanese Investment into
China

Kun-Ming Chen, Hsiu-Hua Rau

*Associate Professor, Department International Trade,
National Chengchi University*

Chia-Ching Lin

Department International Trade, National Chengchi University

Working Paper Series Vol. 2004-30
November 2004

The views expressed in this publication are those of the author(s) and do not necessarily reflect those of the Institute.

No part of this book may be used reproduced in any manner whatsoever without written permission except in the case of brief quotations embodied in articles and reviews. For information, please write to the Centre.

Exchange Rate Movements and Foreign Direct Investment:
Evidence from Taiwanese Investment into China

Kun-Ming Chen, Hsiu-Hua Rau, and Chia-Ching Lin*

Department of International Trade
National Chengchi University

November 8, 2004

* Corresponding author: Kun-Ming Chen, Tel: 886-2-29387515. E-mail: kmchen@nccu.edu.tw. Chen and Rau are Associate Professors, and Lin is a graduate student, Department of International Trade, National Chengchi University, Taipei, Taiwan.

Abstract

This paper examines the impact of exchange rate level and its volatility on outward foreign direct investment (FDI). The diversity in the motives for FDI is considered. Using a real options approach, we show that exchange rate uncertainty has a negative impact on a firm's outward FDI. In addition, while the depreciation of a host country's currency tends to stimulate outward FDI activity of cost-oriented firms, the depreciation tends to deter outward FDI activity of 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.

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 the traditional theories as 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.

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 the 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, recently, considerable work has been done in the area of the exchange rate movements and FDI, but there is still no consensus either in theory or empirical studies. Moreover, previous empirical studies focus on the bilateral investment among the developed countries; few studies analyze the investment behavior in the newly industrializing countries or the developing countries.

As regards the impact of the exchange rate level, Kohlhagen (1977) and Cushman (1985) show that foreign currency depreciation lowers foreign production cost and increases the relative profitability of foreign versus domestic production, and thus stimulating FDI. Froot and Stein (1991) develop a model with an imperfect capital market to explain the connection between exchange rates and FDI. They 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 encouraged FDI, which are consistent with the prediction of above-mentioned theories (Kohlhagen (1977), Cushman (1985), Froot and Stein (1991), Klein and Rosengren (1994), Blonigen (1997), Xing (2002)). In contrast, using Dixit's (1989b) real options framework, Campa (1993) shows that if a firm sets up a foreign subsidiary in order to sell product which is produced in the home country, the appreciation of the host

country's currency will generate higher revenue, thus stimulating FDI. Empirical evidence from wholesale and chemicals industries of the United States in Campa (1993), Bell and Campa (1997) and Tomlin (2000) is consistent with this hypothesis. However, Campa and Goldberg (1995) find that the directions of the effects of exchange rate on FDI are different across industries. In addition, using the data on FDI among the United States and 12 developed countries, Gorg and Wakelin (2002) show that US outward FDI is positively correlated with appreciation in the host country currency while US inward FDI is negatively correlated with appreciation in the dollar.

Another line of research focuses on the effect of exchange rate uncertainty on FDI. Goldberg and Kolstad (1995) argue that risk-averse firms are motivated to engage in international productive diversification. The division of capacity across borders depends on the distributions of both exchange rate and demand shocks. They show that while there will not be any statistical relationship between exchange variability and FDI for risk-neutral firms, exchange variability may stimulate FDI activity for risk-averse firms. In contrast, with a real options approach, Dixit (1989b) and Erdal (2001) show that, with sunk costs involved in FDI, even for risk-neutral firms, exchange rate volatility makes the entry and exit options more valuable and therefore less likely to be exercised, which implies that exchange uncertainty tends to deter FDI activity. Following the model of Dixit and Pindyck (1994) to the case of risk-averse firms, however, Darby, et al. (1999) show that the effects of exchange rate uncertainty on FDI are ambiguous.

Empirical evidence concerning the effects of the exchange rate volatility on FDI is also mixed. Cushman (1985) uses U.S. annual bilateral direct investment flows to five industrialized countries and finds significant increases associated with exchange risk. Similarly, Goldberg and Kolstad (1995) use bilateral foreign direct investment activity between the United States and the United Kingdom, Japan, and Canada and find that exchange rate variability tends to stimulate FDI activity. In contrast, using panel data of U.S. wholesale industries, Campa (1993) shows that exchange rate volatility is negatively correlated with the number of foreign investment. However, Tomlin (2000) illustrates that Campa's results are sensitive to the estimation techniques used. In a more recent study, Gorg and Wakelin (2002) find that there is no significant effect of exchange rate variation on either US outward FDI or inward FDI.

The purpose of this paper is to investigate the effects of changes in exchange rate

on Taiwan's outward FDI into China both theoretical and empirically. Chen (1992), 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. As correctly pointed out by Carruth, Dickerson and Henley (2000), if the impacts of exchange rate changes on FDI are different across industries, analysis based on aggregate data might result in aggregation bias, which exists in most of the previous studies. To illustrate the importance of diversity of motives in understanding the determinants of FDI activity, in this paper we extend Dixit's (1989b) real options model to investigate the effects of exchange rate on the FDI activity of market-oriented firms versus 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.

The remainder of the paper is organized as follows. Dixit's (1989b) model is extended in the following section to compare the differences in the effects of exchange rate on FDI activity of market-oriented firms versus cost-oriented firms. Our empirical model and estimation method are discussed in Section 3, followed in the subsequent section by the presentation of the data and empirical results. Brief concluding remarks are given in the final section.

2. A simple model of FDI and exchange rate

Orthodox investment theory, 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 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. The 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 to wait and enter the market in the future. FDI decisions are made in a more uncertain

environment than domestic investment; especially, the firm faces larger exchange rate risk. Furthermore, FDI generally incurs substantial sunk costs.¹ Hence, a real options approach is more relevant for analyzing the determinants of FDI.

Following Dixit (1989b), a real options approach is used to investigate the relationship between exchange rates and FDI. The objective of multinational enterprises (MNEs) is assumed to be in obtaining maximum expected profits in terms of a home country's currency. In the real option context, an MNE controls the timing of entering the foreign market under the exchange rate uncertainty. To illustrate the importance of the diversity of motives in investigating the determinants of FDI, we focus on two extreme cases according to the location of a firm's production activity and the destination of its product, namely, market-oriented FDI versus cost-oriented FDI. Market-oriented FDI refers to the situation in which the foreign subsidiary of a firm sells output in a given foreign market and incurs all costs in domestic currency. In contrast, cost-oriented FDI refers to the situation in which the foreign subsidiary of a firm exports output to the home market² and incurs all costs in foreign currencies. 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 can produce a unit flow of output at variable costs W_T or W_C , while investing a lump sum k ; W_T represents the variable costs in home currency of producing the good if the MNE chooses to produce it in the home country and then sells it to the foreign market; W_C represents the variable costs in foreign currency in producing the good if the MNE choose to produce it in the host country. For simplicity, we assume that the variable costs comprise wage costs only. Moreover, k is the sunk costs of the entry, which are assumed to be expressed in home currency³.

Suppose next that the MNE faces perfectly competitive markets with output prices P_C and P_T , which represents foreign market price and domestic price, respectively.

¹ 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.

² This phenomenon is referred to as "reverse imports" in the literature.

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 initial exchange rate is exogenous and thus does not influence the firm's value of the option to wait.

Finally, suppose that exchange rate, R , expressed in units of home currency per foreign currency, follows an exogenously geometric Brownian motion

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

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

Following Dixit (1989b), it is assumed that a market-oriented MNE incurs sunk costs to set up a foreign subsidiary in order to market its product which is produced in the home country. It remits the profits of the subsidiary back to its home country.⁴ Hence, its profit flows per period are

$$\pi(R) = P_C R - W_T.$$

Because we focus on the timing of entry, we assume a potential entrant stays in the market forever after entering the market⁵. The firm faces a binary decision problem each period as follows:

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

where V_0 is the optimal expected net present value; $\xi_M(R) = P_C R / (\rho - \mu) - W_T / \rho$ represents the expected present value that stays in the market forever, ρ is the discount rate. The former term on the right-hand side, $\xi_M(R) - k$, is the net entry value and the latter term, $[1/(1 + \Delta t \rho)] E[V_0(R') | R]$, is the value of the option to wait.

Since the profit function in this model is an increasing function in R , according to Dixit (1989b), 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. 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

$$R_H = \left(\frac{W_T}{\rho} + k \right) \frac{(\rho - \mu) \cdot \beta}{P_C \cdot (\beta - 1)}. \quad (2)$$

⁴ It is the case analyzed in Campa (1993). This definition is also analogous to the definition of exporting or import-competing firm in Erdal (2001).

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

where $\beta = \sigma^{-2}[-(\mu - 0.5\sigma^2) + \sqrt{(\mu - 0.5\sigma^2)^2 + 2\sigma^2\rho}]$. From Equation (2), it can be shown that⁶

$$\frac{dR_H}{dk} > 0, \quad \frac{dR_H}{dW_T} > 0, \quad \frac{dR_H}{d\sigma} > 0, \quad \frac{dR_H}{d\mu} < 0. \quad (3)$$

Cost-oriented firm

As for a cost-oriented firm, it is assumed that it incurs sunk costs to set up a foreign subsidiary for manufacturing its product which is wholly exported back to the home country, with a view to reducing production costs. Therefore, the profit flows per period become

$$\pi(R) = P_T - W_C R.$$

According to the profit flows, it is obvious that the cost-oriented firm benefits from a depreciation of 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 $\xi_C(R) = P_T/\rho - W_C R/(\rho - \mu)$ 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.

$$V_0(R) = \max \left\{ \xi_C(R) - k, \frac{1}{1+\Delta t\rho} E[V_0(R')|R] \right\}. \quad (4)$$

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

$$R_L = \left(\frac{P_T}{\rho} - k \right) \frac{(\rho - \mu) \cdot \alpha}{W_C \cdot (\alpha + 1)}. \quad (5)$$

where $\alpha = \sigma^{-2}[(\mu - 0.5\sigma^2) + \sqrt{(\mu - 0.5\sigma^2)^2 + 2\sigma^2\rho}]$. From Equation (5), it can be shown that⁷

$$\frac{dR_L}{dk} < 0, \quad \frac{dR_L}{dW_C} < 0, \quad \frac{dR_L}{d\sigma} < 0, \quad \frac{dR_L}{d\mu} < 0. \quad (6)$$

⁶ See Appendix 1 for the derivation.

⁷ Ibid.

Determinants of FDI

From Equations (3) and (6), 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 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 two types of firms. This is because, given the irreversibility of investment, the higher the entry costs are, the higher the entry trigger rate will be of the market-oriented firms and the lower the entry trigger rate will be of the cost-oriented firms. As a result, the number of FDI decreases with the increase in k . It worth noting that, if sunk investment costs are zero, then the volatility would have no effect on the entry decision⁸. 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 number of FDI.

Third, the expected signs of the wage rate are also the same for these two types of firms. For a market-oriented firm, it incurs its variable costs in the home country. The higher the domestic wage rate is, the less profitable its sales will be in the foreign market. Consequently, it will have a lower incentive to set up a foreign subsidiary for marketing. Similarly, the higher the foreign wage rate is, the higher the variable costs involved in foreign production will be. Therefore, a cost-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 its profits in terms of home currency are higher when remitting them back to the home country. However, for the cost-oriented firms, an appreciation of foreign currency implies higher variable costs in terms of home currency. As a result, the profits of it's a foreign subsidiary will be lower. Therefore, the expected sign of the exchange rate for market-oriented firms is positive,

⁸ It is so obvious that we omit the derivations.

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 is positive whereas the expected sign for cost-oriented firms is negative, based on the similar reasoning as mentioned above.

To sum up, the effects of exchange rate uncertainty, sunk entry costs and wage rates on FDI are negative, regardless of whether the firm is market-oriented or cost-oriented. Furthermore, the effects of exchange rate level and its trend on FDI are positive for market-oriented firms, and negative for cost-oriented firms.

Table 1 Expected signs of the determinants of FDI

Types \ Variables	Exchange Rate (R)	Exchange Rate Trend (μ)	Exchange Rate Volatility (σ)	Sunk Costs	Home Country Wage Rate (W_T)	Host Country Wage Rate (W_C)
Market-oriented Firms	+	+	-	-	-	-
Cost-oriented Firms	-	-	-	-	-	-

3. Empirical model

Based on the theoretical framework of this paper, an empirical model is established as follows:

$$\begin{aligned}
FDI_{i,t}^* = & \alpha_i + \beta_1 R_{t-1} + \beta_2 \mu_t + \beta_3 \sigma_t + \beta_4 Wage_{i,t-1} + \beta_5 Sunk_i * \sigma_t \\
& + \beta_6 Market_i * R_{t-1} + \beta_7 Cost_i * R_{t-1} \\
& + \beta_8 Market_i * \mu_t + \beta_9 Cost_i * \mu_t \\
& + \beta_{10} Market_i * Wage_{i,t-1} + \beta_{11} Cost_i * Wage_{i,t-1} \\
& + \beta_{12} Trend_t + \beta_{13} Dummy_t + \varepsilon_{it}^*
\end{aligned} \tag{7}$$

Here, subscript i refers to industries; subscript t refers to time periods; α_i and β_j ($j=1, \dots, 13$) are parameters; and ε_{it}^* 's are disturbance terms. The definitions of the variables in Equation (7) are explained as follows:

$FDI_{i,t}^*$: the desired number of new FDI cases of industry i at time t , which is

divided by real GDP of the host country to control for changes in the size of the host country.

R_{t-1} : the one-period lagged real exchange rate of the home country, 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, 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 the industries without sunk investment costs, and negative for those industries with sunk investment costs.

$Wage_{i,t-1}$: the ratio of a host country's one-period lagged real wage rates over a home country's one-period lagged real wage rates. One alternative for market-oriented FDI is to produce abroad; similarly, one alternative for cost-oriented FDI is to produce in the home country. To control for these alternatives, the relative wage rates instead of the absolute wage rates are used in our empirical model. The expected sign of this variable for market-oriented firms is positive and negative for cost-oriented firms.

$Sunk_i$: 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 time-related variables.

$Dummy_i$: During our sample period, Taiwan's government had 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,

$$FDI_{i,t} = \begin{cases} FDI_{i,t}^*, & \text{if } FDI_{i,t}^* > 0 \\ 0 & , \text{ if } FDI_{i,t}^* \leq 0 \end{cases} \quad (8)$$

where $FDI_{i,t}$ is the observed new FDI cases. Since the range of dependent variable is constrained, a Quasi Maximum Likelihood Tobit Model is adopted to fit the data.⁹

Under this setting, the validity of our theoretical results about differences in the effects of exchange rate on FDI activity of these two types of firms can be tested. According to the prediction of our theory, we expect that $\beta_7, \beta_9, \beta_{11} < 0$ and $\beta_6, \beta_8, \beta_{10} > 0$.

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. As for exchange rates, the exchange rates between New Taiwan Dollar (NTD) and Yuan are calculated from the ratio of exchange rates of NTD and U.S. Dollar (USD), and exchange rates of Yuan and USD. Several measures of exchange rate uncertainty have been proposed in the literature. The details are presented in Appendix 2. To test robustness of our empirical results, many of these measures are used in our estimation.

To differentiate the motives of FDI across industries, several criteria are used to define market-oriented industries and cost-oriented industries. It turns out that among

⁹ See Hsiao (2003), Ch.8.

27 industries there are seven market-oriented industries, and most of them are in the wholesale and service sectors. We also identify eight cost-oriented industries, where all of them are in the manufacturing sector. The industries are also classified according to the magnitude of sunk costs involved in their FDI activity. Four criteria are used. The details are discussed in Appendix 2.

Summary statistics of the data are shown in Table 2. These statistics reveal several stylized facts. First, Taiwan's currency, NTD, appreciated against China's currency, Yuan, by 21.4% between 1991 and 2002, whereas NTD depreciated against USD by 28.2% during the same period. Second, the annual average wage rates of Taiwan measured in terms of the local currency rose by 50.6% from 1991 to 2002, which is greater than nine times the annual average wage rates of China in 2002. Third, the average annual growth rate of Taiwan's FDI cases in China is 16.72% between 1991 and 2002. These stylized facts illuminate possible linkages between Taiwanese outward FDI into China and the exchange rate changes as well as relative wage rates.

Table 2 Summary Statistics

	Min	Max	Mean	Standard deviation
Outward FDI cases	0	1214	84.1667	190.5201
R	2.6263	4.2271	3.5313	0.4637
μ	-0.0190	0.0131	-0.0008	0.0101
σ	0.0229	0.0637	0.0353	0.0135
μ_T	-0.4201	0.3229	-0.0009	0.2403
σ_T	0.1119	0.3122	0.1727	0.0663
σ_D	0.0258	0.0630	0.0361	0.0129
<i>Wage</i>	0.3171	1.2190	0.7320	0.1854

Notes: μ and σ are the measures used in Campa (1993); μ_T and σ_T are the measures used in Tsay (2002) and σ_D is used in Darby et al (1999). See Appendix 2 for the definitions and calculations of these variables.

Empirical results

Table 3 summarizes the results of the Tobit estimation. The first two columns do not include industry dummies that differentiate the motives involved in FDI activity, and thus can be treated as our benchmark models. In these models, all signs of the estimated marginal effects are negative, As shown in column 1, the coefficient of σ is insignificant, whereas that of *Sunk** σ is significant, indicating that the higher the volatility of the real exchange rate is, the less likely the firms are willing to invest abroad, particularly for the firms in industries with substantial sunk investment costs.

Moreover, this result supports our prediction that the exchange rate volatility would not have significantly negative effect on FDI of the Taiwanese industries that bear less sunk investment costs.

Furthermore, as shown in column 2, an appreciation of NTD will stimulate Taiwanese investment in China, particularly for the industries with larger sunk investment costs, which is demonstrated in the significant negative coefficient of $Sunk * R_{t-1}$. The coefficient of relative wage rates, $Wage$, has a negative sign, implying that lower relative wage rates are one of the reasons for Taiwanese firms to invest in China. This is consistent with the investigation results published by Taiwan Investment Commission in 2003, which indicates that there are 81.46% of Taiwanese firms to invest in China for the reason of cutting down labor costs.

The estimation in column 3 tries to identify the differences in effects of real exchange rates on FDI among different motives while the estimation in column 4 tries to identify the differences in effects of real relative wage rates on FDI across industries. All variables have the signs predicted by the theory. The coefficients of $Market * R_{t-1}$ and $Market * \mu$ are positive, whereas those of $Cost * R_{t-1}$ and $Cost * \mu$ are negative as expected, implying that a depreciation of NTD will stimulate the FDI activity of market-oriented firms, but deter that of cost-oriented firms. Furthermore, the coefficients of $Market * Wage$ is positive and that of $Cost * Wage$ is negative, indicating that an increase in real relative wage rates in the host country tends to deter FDI of cost-oriented firms, but stimulate FDI of market-oriented firms. These results demonstrate that the determinants of FDI activity indeed vary with its motives, as proposed in this paper.

Table 4 summarizes the Tobit estimation by some selected measures of sunk investment costs and volatility of real exchange rates as suggested in the literature. Three different measures of exchange rate uncertainty and four different measures of sunk costs are used. In general, we obtain similar results as in Table 3. Therefore, our empirical results are robust to the measurement of sunk costs and exchange rate uncertainty.

To sum up, with industry panel data on Taiwan's outward FDI in China over the period 1991-2002, our empirical findings indicate that the real exchange rate level and its volatility along with the real relative wage rate have had a significant impact on Taiwanese firms' outward FDI in China. In particular, the appreciation of NTD and

the increase in relative wage of Taiwan seem to have stimulated Taiwanese firms to invest in China, which are consistent with general beliefs.¹⁰ In addition, the increasing volatility of exchange rate of NTD might have deterred Taiwanese firms' FDI activity.

¹⁰ See Chen (1992), and Investment Commission, Ministry of Economic Affairs, ROC, "*Survey on Taiwanese Firms in Mainland*", 1999~2003

Table 3 Tobit estimation of the determinants of FDI: Marginal Effects

Dependent Variable: Approved FDI Cases/GDP

Total Number of Observations: 324

Number of Positive Observations: 292

Independent Variables	(1)	(2)	(3)	(4)
R_{t-1}	-0.0314 ^a (-8.91)	-0.0260 ^a (-6.91)	-0.0329 ^a (-8.08)	-0.0319 ^a (-9.16)
μ	-1.0070 ^a (-6.38)	-1.0394 ^a (-6.62)	-1.0631 ^a (-5.71)	-1.0330 ^a (-6.63)
σ	-0.0627 (-0.67)	-0.2251 ^a (-2.85)	-0.0376 (-0.41)	-0.0458 (-0.49)
<i>Wage</i>	-0.0490 ^a (-2.77)	-0.0551 ^a (-3.13)	-0.0614 ^a (-3.55)	-0.0568 ^a (-3.07)
<i>Sunk*σ</i>	-0.4624 ^a (-3.23)		-0.5168 ^a (-3.68)	-0.4971 ^a (-3.50)
<i>Sunk*R_{t-1}</i>		-0.0166 ^a (-3.98)		
<i>Market*R_{t-1}</i>			0.0089 ^b (1.82)	
<i>Cost*R_{t-1}</i>			-0.0066 (-1.44)	
<i>Market*μ</i>			0.5397 ^a (2.21)	
<i>Cost*μ</i>			-0.4745 ^a (-2.22)	
<i>Market*Wage</i>				0.0396 ^a (2.44)
<i>Cost*Wage</i>				-0.0231 (-1.47)
<i>Trend</i>	0.0053 ^a (5.17)	0.0057 ^a (5.49)	0.0061 ^a (6.00)	0.0056 ^a (5.47)
<i>Date Dummy</i>	0.0255 ^a (11.59)	0.0254 ^a (11.60)	0.0257 ^a (12.05)	0.0256 ^a (11.77)
Likelihood ratio test	465.78	477.17	526.79	491.16
AIC	-335.81	-338.00	-339.86	-336.96

Notes: t-statistics are in parentheses; ^a and ^b denote t-statistics are significant at the 1% and 5% confidence levels, respectively. All p-values of likelihood ratio tests are less than 0.005. Each equation also includes 27 industry dummies.

Table 4 Tobit estimation by some selected measures of sunk investment costs and volatility of the real exchange rate: Marginal Effect

Dependent Variable: Approved FDI Cases/GDP

Total Number of Observations: 324

Number of Positive Observations: 292

Independent Variables	(5)	(6)	(7)	(8)	(9)
R_{t-1}	-0.0329 ^a (-8.12)	-0.0326 ^a (-7.98)	-0.0326 ^a (-7.91)	-0.0321 ^a (-7.79)	-0.0319 ^a (-7.77)
μ		-1.0644 ^a (-5.70)	-1.0674 ^a (-5.68)	-1.0709 ^a (-5.69)	-1.0740 ^a (-5.71)
σ			-0.1138 (-1.26)	-0.1245 (-1.36)	-0.1366 (-1.59)
μ_T	-0.0441 ^a (-5.69)				
σ_T	0.0016 (0.08)				
σ_D		-0.0580 (-0.59)			
<i>Wage</i>	-0.0611 ^a (-3.56)	-0.0603 ^a (-3.47)	-0.0626 ^a (-3.59)	-0.0628 ^a (-3.59)	-0.0630 ^a (-3.61)
<i>Sunk</i> * σ_T	-0.1037 ^a (-3.62)				
<i>Sunk</i> * σ_D		-0.4739 ^a (-3.18)			
<i>Sunk2</i> * σ			-0.3371 ^b (-2.30)		
<i>Sunk3</i> * σ				-0.2709 ^b (-1.92)	
<i>Sunk4</i> * σ					-0.3529 ^b (-2.21)
<i>Market</i> * R_{t-1}	0.0091 ^b (1.88)	0.0088 ^b (1.79)	0.0078 (1.58)	0.0067 (1.37)	0.0069 (1.40)
<i>Cost</i> * R_{t-1}	-0.0068 (-1.48)	-0.0066 (-1.43)	-0.0065 (-1.39)	-0.0073 (-1.57)	-0.0079 ^b (-1.70)
<i>Market</i> * μ		0.5578 ^b (2.27)	0.5457 ^b (2.21)	0.5502 ^b (2.23)	0.5518 ^b (2.24)
<i>Cost</i> * μ		-0.4658 ^b (-2.17)	-0.4737 ^b (-2.19)	-0.4678 ^b (-2.16)	-0.4634 ^b (-2.14)
<i>Market</i> * μ_T	0.0233 ^b (2.27)				
<i>Cost</i> * μ_T	-0.0218 ^a (-2.43)				
<i>Trend</i>	0.0061 ^a (6.04)	0.0060 ^a (5.83)	0.0062 ^a (5.99)	0.0062 ^a (5.98)	0.0062 ^a (6.00)
<i>Date Dummy</i>	0.0258 ^a (12.10)	0.0258 ^a (12.06)	0.0256 ^a (11.87)	0.0256 ^a (11.84)	0.0256 ^a (11.86)
Likelihood ratio test	532.20	516.71	505.73	501.76	504.62
AIC	-340.87	-338.12	-336.31	-335.60	-336.11

Notes: t-statistics are in parentheses; ^a and ^b denote t-statistics are significant at the 1% and 5% confidence levels, respectively. All p-values of likelihood ratio tests are less than 0.005. Each equation also includes 27 industry dummies.

5. Conclusion

This paper examines how exchange rate changes influence FDI activity theoretically and empirically. The real options framework of Dixit (1989b) is extended 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 a depreciation of a host country's currency tends to stimulate the outward FDI activity of cost-oriented firms, the depreciation tends 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 along with relative wage rates 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.

This paper can be extended in several directions: First, a more general model needs to be developed in order to compare the differences in the determinants across all industries. Second, with data on the exit of investing firms from foreign markets, the real options theory can be tested more effectively. Finally, the option of investing into the third country can be incorporated into the model so that the effect of covariance between exchange rates, as suggested by Becker and Hall (2003), can be examined.

Appendix 1 The Derivation of Equations (3) and (6)

This appendix describes the derivation of equations (3) and (6) in Section 2 of the main text. The derivation of $\partial R_H/\partial k$, $\partial R_H/\partial W_T$, $\partial R_L/\partial k$ and $\partial R_L/\partial W_C$ is so obvious that we omit the proof. To save space, we use the following results in Dixit (1989b, p.626):

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

and

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

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

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

and

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

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

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

and

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

Next, according to Equation (2) in Section 2, differentiating R_H with respect to μ , we have

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

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 $\mu = \rho$, thus we have $\phi < 0$. Consequently, we have $\partial R_H/\partial\mu < 0$.

Similarly, from Equation (5) in Section 2, differentiating R_L with respect to μ , we have

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

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

Note that

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

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

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

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

Appendix 2 Data Description

The annual approved cases of Taiwan's outward FDI in China, classified into 27 industries according to 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, ROC, 2004. The real GDP of China is measured at the price of 1995 in billions of Yuan, which is compiled from the database of Taiwan Economic Journal (TEJ).

The level of the real exchange rate, R , is the average bilateral real exchange rate, expressed in units of NTD per Yuan. It is calculated with a nominal exchange rate of NTD to USD, and that of Yuan to USD, and deflated with the CPI of Taiwan and the CPI of China, respectively. The data are compiled from AREMOS database, Ministry

of Education, ROC (AREMOS).

The real relative wage index, *Wage*, 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.

Several measures of the trend and the volatility of the real exchange rate are suggested in the literature. Following Campa (1993), μ and σ are defined as an average and a standard deviation of the monthly changes in the log of the real exchange rate over the past 24 months, respectively. That is

$$\sigma = \left[\frac{1}{T-1} \sum_{i=1}^T (r_i - \mu)^2 \right]^{\frac{1}{2}}, \quad \mu = \frac{1}{T} \sum_{i=1}^T r_i$$

where $r_i = \log R_i - \log R_{i-1}$, $T = 24$.

According to Darby et al. (1999), another measure of the volatility is defined as follows:

$$\sigma_D = \left[\frac{1}{T} \sum_{i=1}^T r_i^2 \right]^{\frac{1}{2}}$$

When using discrete data to approximate a continuous-time geometric Brownian motion process, Tsay (2002, p. 229) suggests that the suitable proxies for the trend and the volatility of the real exchange rate are

$$\sigma_T = \frac{\sigma}{\sqrt{\Delta}}, \quad \mu_T = \frac{\mu}{\Delta} + \frac{\sigma^2}{2}$$

where Δ is the space time interval, equal to $1/T$. The monthly exchange rates are compiled from the database of TEJ.

As for the dummy variables, *Market*, *Cost*, *Sunk*, the details are listed in Table A1.

Table A1 Classification of industries by motives and sunk costs of FDI

Dummy Variable	Description
<i>Market</i>	<p>Its value is 1 if the industry satisfies the following two conditions simultaneously, 0 otherwise:</p> <p>(1) One of the top ten industries by percentage of firms that sell products in China.</p> <p>(2) One of the last ten industries by percentage of firms that manufacture products in China.</p>
<i>Cost</i>	<p>Its value is 1 if the industry satisfies the following two conditions simultaneously, 0 otherwise:</p> <p>(1) One of the top ten industries by percentage of firms that export products back to Taiwan.</p> <p>(2) One of the top ten industries by percentage of firms that manufacture products in China.</p>
<i>Sunk</i>	Its value is 1 for top ten industries by the percentage of Taiwanese firms with R&D expenditures in China; 0 otherwise.
<i>Sunk2</i>	Its value is 1 for top ten industries by the percentage of Taiwanese firms that get technology from their own R&D expenditures in China; 0 otherwise.
<i>Sunk3</i>	Its value is 1 for top ten industries by the percentage of Taiwanese firms with marketing departments in China; 0 otherwise.
<i>Sunk4</i>	Its value is 1 for top ten industries by the percentage of Taiwanese firms with R&D and marketing departments in China; 0 otherwise.

Notes: It turns out that market-oriented industries include construction instruments, wholesale & retail, trade, restaurant, transportation, storage and services. Cost-oriented industries include textile, chemicals, rubber products, plastic products, machinery equipment, electronic & electric appliances, transport equipment and precision instruments. Source: “*Survey on Taiwanese Firms in Mainland China*, 1999~2002, Investment Commission, Ministry of Economic Affairs. In their survey, Liu and Lin (2001) find that the investing firms in most of the above-mentioned cost-oriented industries exported a substantial portion of their products back to Taiwan.

References

- Becker, B. and S.G. Hall (2003), "Foreign direct investment in industrial R&D and exchange rate uncertainty in the UK", working paper, Leverhulme Centre, University of Nottingham.
- Blonigen, B.A. (1997), "Firm-specific assets and the link between exchange rates and foreign direct investment", *American Economic Review*, 87(0), 447-465.
- Campa, J. (1993), "Entry by foreign firms in the United States under exchange rate uncertainty," *Review of Economics and Statistics*, 75, 614-622.
- Campa, J. and L.S. Goldberg (1995), "Investment in manufacturing, exchange rates and external exposure", *Journal of International Economics*, 38, 297-320.
- Chen, T.J. (1992), "Determinants of Taiwan's direct foreign investment: the case of a newly industrializing country", *Journal of Development Economics*, 39, 197-407.
- Chen, J.R. and C.H., Yang (1999), "Determinants of Taiwanese foreign direct investment-comparison between expansionary FDI and defensive FDI", *Taiwan Economic Review*, 27, 215-240.
- Carruth, A., A. Dickerson and A. Henley (2000), "What do we know about investment under uncertainty", *Journal of Economic Surveys*, 14, 120-153.
- Cushman, D.O. (1985), "Real exchange rate risk, expectations, and the level of direct investment", *Review of Economics and Statistics*, 67, 297-308.
- Darby, J., A.H. Hallett, J. Ireland, and L. Piscitelli (1999), "The impact of exchange rate uncertainty on the level of investment", *Economic Journal*, 109, 55-67.
- Dixit, A.K. (1989a), "Hysteresis, import penetration, and exchange rate pass-through", *Quarterly Journal of Economics*, 104, 205-228.
- Dixit, A.K. (1989b), "Entry and exit decisions under uncertainty", *Journal of Political Economy*, 97, 620-638.
- Dixit, A.K. and R.S. Pindyck (1994), *Investment Under Uncertainty*, Princeton: Princeton University Press.
- Erdal, B. (2001), "Investment decisions under real exchange rate uncertainty", *Central Bank Review*, 1, 25-47.
- Froot, K.A., and J.C. Stein (1991), "Exchanges rates and foreign direct investment: an imperfect capital markets approach", *Quarterly Journal of Economics*, 106, 1191-1217.
- Goldberg, L.S. and C.D. Kolstad (1995), "Foreign direct investment, exchange rate variability and demand uncertainty", *International Economic Review*, 36, 855-873.
- Gorg, H. and K. Wakelin (2002), "The impact of exchange rate variability on US direct investment", *Manchester School*, 70, 380-397.
- Hsiao, C., *Analysis of Panel Data* (2003), 2nd edition. Cambridge: Cambridge University Press.
- Iannizzotto, M. and N.J. Miller (2002), "The effect of exchange rate uncertainty on foreign direct investment in the United Kingdom", working paper, International Economic Association World Congress, Paris.
- Investment Commission, Ministry of Economic Affairs, ROC (2004), *Statistics on Overseas Chinese & Foreign Investment, Technical Cooperation, Outward Investment, Outward Technical Cooperation*.

- Investment Commission, Ministry of Economic Affairs, ROC, *Survey on Taiwanese Firms in Mainland China*, 1999~2003.
- Klein, M.W. and E.S. Rosengren (1994), "The real exchange rate and foreign direct investment in the United States: relative wealth vs. relative wage effects", *Journal of International Economics*, 36, 373-389.
- Kohlhagen, S.W. (1977), "Exchange rate changes, profitability, and direct foreign investment", *Southern Economic Journal*, 44, 376-383.
- Laar, Mindel van de (2000), "Foreign direct investment decisions under uncertainty in central and eastern Europe", Working Paper, Business Investment Research Center, Maastricht University.
- Liu, B.J. and H.L. Lin (2001), "Reverse imports and outward direct investment", *Taiwan Economic Review*, 29, 479-510.
- Tsay, R.S. (2002), *Analysis of Financial Time Series*. New York: John Wiley & Sons, Inc.
- Tomlin, K.M. (2000), "The effects of model specification on foreign direct investment models: an application of count data models", *Southern Economic Journal*, 67, 460-468.
- Xing, Y. (2002), "The impact of real exchange rates on Japanese direct investment in China's manufacturing: an empirical assessment", Working paper, International Development Series, International University of Japan..