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THE IMPACT OF EXCHANGE RATE MOVEMENTS ON FOREIGN DIRECT INVESTMENT: MARKET-ORIENTED VERSUS COST-ORIENTED

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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 the 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

I. 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

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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 has recently 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 real options framework (1989a), 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 generates higher revenue, thus stimulating FDI. Empirical evidence from the wholesale and chemicals industries in the United States in Campa (1993) and Tomlin (2000) is consistent with this hypothesis. However, Goldberg (1993) finds that the directions of the effects of the exchange rate on FDI are different across industries. Using data on FDI among the United States and 12 developed countries, Gorg and Wakelin (2002) show that US outward FDI is positively correlated with an appreciation in the host country currency, while US 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

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

effects of changes in the exchange rate on market-oriented FDI versus cost-oriented FDI both theoretically and empirically.

We first apply Dixit's real options model (1989a) 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 a host country's currency will stimulate the FDI of market-oriented firms, but will 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 T.-J. Chen (1992) and J.-R. 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., T.-J. Chen 1992; C.-H. Chen 1996; J.-R. Chen and Yang 1999; Henley, Kirkpatrick, and Wilde 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 (1989a) model is presented and the effects of exchange rate movements on the FDI activity of market-oriented firms versus cost-oriented firms are illustrated. Section III discusses our empirical model and estimation method, followed in the subsequent section by a presentation of the data and empirical results. Brief concluding remarks are given in the final section.

II. A SIMPLE MODEL OF FOREIGN DIRECT INVESTMENT AND THE EXCHANGE RATE

An orthodox investment theory, the net present value (NPV) theory, assumes that an 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 FDI timing.

Following Dixit (1989a), 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. The following will show that the effects of the exchange rate on FDI are rather different under these two cases.

To begin with, we assume that a risk-neutral multinational enterprise (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 to be expressed in the home currency.[3] For simplicity, we assume that the variable costs are comprised of 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 Wiener process.[5]

[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.

[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 (1989b) 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] Investigating the real exchange rates of the major industrialized countries' currencies, Frankel and Rose (1995) and Sarno and Taylor (2002) indicate that one generally cannot reject the random walk hypothesis. Furthermore, De Grauwe (1996) and Sarantis (1999) show that real bilateral exchange rates for the major industrial countries exhibited very long cycles and substantial drifts. Therefore, the specification of the stochastic process of the exchange rate as a Brownian motion with drift seems consistent with previous empirical evidence.

A. *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:

$$\pi_M(R) = P_f R - W_f R,$$

where P_f is the foreign market price and W_f is the foreign wage rate. These two variables are expressed in foreign currency. The subscript of M refers to a market-oriented firm hereafter.

Because we focus on the timing of entry, we assume a potential entrant stays in the market forever after entering the market.[6] The firm faces a binary decision problem each period as follows:

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

where V_0 is the optimal expected net present value; $\xi_M(R) = (P_f - W_f)R/(\rho - \mu)$ represents the expected present value that stays in the market forever; ρ is the discount rate; Δt is the time interval; and R' is the exchange rate in period $t + 1$.[7] The former term on the right-hand side, $\xi_M(R) - k$, is the net entry value and the latter term, $[1/(1 + \Delta t\rho)]\mathrm{E}[V_0(R')|R]$, is the value of the option to wait.

Since the profit function in this model is an increasing function in R, there is a cut-off 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.[8] In other words, the lower the value of R_H, the higher the probability 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 $\beta = \sigma^{-2}\left[-(\mu - 0.5\sigma^2) + \sqrt{(\mu - 0.5\sigma^2)^2 + 2\sigma^2\rho}\right]$. From equation (3), it can be shown that[9]

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

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

[7] Notice that the expected present value of the firm is convergent only if $\mu < \rho$ (see Dixit 1989a, p. 624). Therefore, in this paper it is assumed that $\mu < \rho$.

[8] See Dixit and Pindyck (1994, p.128).

[9] See Appendix I for the derivation.

B. *Cost-Oriented Firm*

Cost-oriented FDI refers to the situation in which a firm sets up a foreign subsidiary to produce, and exports its output back to the home country[10] 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:

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

where P_d is the domestic market price in domestic currency. The subscript of C refers to a cost-oriented firm hereafter.

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

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

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

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

where $\alpha = \sigma^{-2}\left[(\mu - 0.5\sigma^2) + \sqrt{(\mu - 0.5\sigma^2)^2 + 2\sigma^2\rho}\right]$. From equation (6), it can be shown that[11]

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

C. *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

[10] This phenomenon is referred to as "reverse imports" in the literature. Liu and Lin (2001) find that the reverse imports of Taiwanese multinational firms in the electronics and electric appliances, metal products, and textile industries account for more than 30% of total revenue in their foreign subsidiaries.

[11] See footnote 9.

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.

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 be that are requested to compensate the opportunity loss. Thus, the entry trigger rate will be higher for the market-oriented firms and the entry trigger rate will be lower 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.[12] 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 benefit 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

[12] Derivations were deemed unnecessary and have been omitted.

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, while the expected signs for cost-oriented firms are negative, based on the similar reasoning as mentioned above.

III. EMPIRICAL MODEL

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

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

Here, subscript i refers to industries, subscript t refers to time periods, α_i and β_j ($j = 1, \ldots, 11$) 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, NT\$) versus China's currency (renminbi, RMB) , in which nominal exchange rates are deflated with the prices of the respective countries to control 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 and 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 and 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, rather than 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 number of new FDI cases in several years is 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 nonnegative; that is:

$$FDI_{i,t} = \begin{cases} FDI^*_{i,t}, & \text{if } FDI^*_{i,t} > 0 \\ 0, & \text{if } FDI^*_{i,t} \leq 0, \end{cases} \tag{9}$$

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.[13]

IV. THE DATA AND EMPIRICAL RESULTS

A. *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 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 sources of the data are described in Appendix II.

As shown in Table 2 and Figure 1, the electronics and electric industries have accounted for a significant and increasing share of FDI cases in Taiwanese investment into China, particularly after 1997. Their share has been around 30% in recent years. Outward investment from service sector has also exhibited an increasing trend. In contrast, the investment cases from the chemicals and plastic products, and the food and beverage industries have declined from the peak of the early 1990s. Investment cases from precision instruments and metal products also each account for a considerable and stable share of Taiwanese outward FDI.

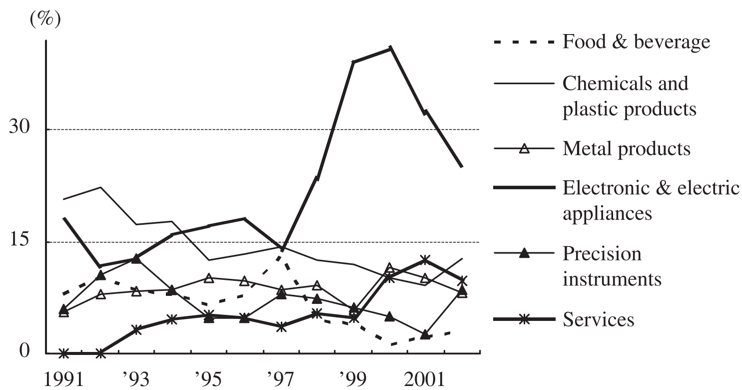
[13] See Hsiao (2003, chap. 8).

TABLE 2

Taiwan's Outward FDI Cases in China, 1991–2002

	1991–93	1994–96	1997–99	2000–2002	1991–2002
Selected industries:					
Food and beverage	837	135	1,227	129	2,328
Chemicals and plastic products	1,723	276	1,469	589	4,057
Metal products	810	166	900	474	2,350
Precision instruments	1,223	121	823	339	2,506
Electronics and electric appliances	1,263	301	1,704	1,515	4,783
Services	305	86	397	538	1,326
All Industry	9,830	1,801	10,497	5,142	27,270

Fig. 1. Percentages of Outward FDI Cases in China for Some Selected Industries



The exchange rates between NT$ and RMB are calculated from the ratio of exchange rates of NT$ and US dollar (US$), and the exchange rates of RMB and US$. Several measures of trend and volatility of the real exchange rate have been proposed in the literature. Following Tsay (2002, p. 229), we first use a modified average and a modified standard deviation of the monthly change in the logarithm of the real exchange rate to stand for the trend and volatility of the real exchange rates, which are designed to approximate a continuous-time geometric Brownian motion process. We then use a GARCH process to estimate the conditional mean and variance of the real exchange rate as the other measures of its trend and volatility, since some studies such as Pozo (1992) note that exchange rates often exhibit persistent behavior.[14]

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

TABLE 3

Summary Statistics

	Mean	Min	Max	Standard Deviation
Real exchange rate	3.5313	2.6263	4.2271	0.4637
Real relative wage rate	0.0544	0.0150	0.1438	0.0273
Percentage of sales in China in total sales in a market-oriented industry	90.9	46.2	100.0	15.5
Percentage of reverse-imports in total sales in a cost-oriented industry	49.9	25.0	97.0	26.0
Percentage of subsidiaries with R&D and marketing departments in a high sunk cost industry	66.7	40.0	87.5	17.5

The sunk investment costs dummy ($Sunk_i$) value is 1 for an industry that 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. Otherwise, the value of $Sunk_i$ is 0. According to these criteria, the industries with high sunk investment costs in our sample include food and beverage processing, chemicals, nonmetallic minerals, machinery equipment, and precision instruments.[15] Taiwanese official surveys reveal that Taiwanese investors in China tend to invest in local distribution channels in order to penetrate into the very competitive markets in these industries. As shown in Table 3, many investing firms in these industries have set up marketing and R&D departments in the host country.[16]

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. Otherwise, the value of $Market_i$ is 0. Market-oriented industries in our sample include mining, construction, restaurant, transportation, and storage. Most of these industries belong to the service sector, in which most of their products are nontradable, and the products of the mining industry are also known for their considerable transportation costs. Consequently, these industries tend to have high percentages of sales in China in their total revenue (Table 3).

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

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

[16] See Republic of China, Ministry of Economic Affairs, Investment Commission, *Survey on Taiwanese Firms in Mainland China* (Taipei), 1999–2003 issues.

TABLE 4

Tobit Estimation of the Determinants of FDI

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

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 ***, **, and * denote that the test statistics are significant at the 1%, 5%, and 10% confidence levels, respectively. Since the expected signs of all explanatory variables are known from our theoretical model, a one-tail test is used.

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. Otherwise, the value of $Cost_i$ is 0. It turns out that the cost-oriented industries in our sample are electronics and electric appliances and plastic products. Taiwanese official surveys reveal that there are high percentages of foreign subsidiaries and parent firms in these two industries that have either a vertical or a horizontal relationship.[17] This implies that the cost consideration in these firms' decision to relocate their production activities is very important. The percentages of reverse-imports of these two industries from China are illustrated in Table 3.

B. *Empirical Results*

Table 4 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 measures of the trend and volatility of real exchange rates (2002) are used, while the measures estimated from a GARCH model are adopted in the other equations reported in columns 4, 5, and 6.

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 $Sunk_i \times \sigma_t$ 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 the 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 $Market_i \times R_{t-1}$ and $Market_i \times \mu_t$ are significantly positive, whereas those of $Cost_i \times R_{t-1}$ and $Cost_i \times \mu_t$ are significantly negative. Furthermore, Wald-test statistics in the same column indicate that the null hypothesis—the coefficients of $Market_i \times R_{t-1}$ and $Cost_i \times R_{t-1}$ are equal, or the null hypothesis—the coefficients of $Market_i \times \mu_t$ and $Cost_i \times \mu_t$ are equal, is rejected at the 5% level. These results imply that, relative to market-oriented firms, the depreciation of a home country's currency is more likely to deter FDI activity of cost-oriented

[17] See Republic of China, Ministry of Economic Affairs, Bureau of Statistics, *Survey on Outward Foreign Direct Investment* (Taipei), 1999–2001 issues.

firms. They also demonstrate 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.

It is worth noting that, as shown in column 3 of Table 4, since the estimated coefficients for R_{t-1} and $Market_i \times R_{t-1}$ are –0.0061 and 0.0013, respectively, the total effect from R_{t-1} on market-oriented FDI seems to be negative. Similarly, the estimated coefficients for μ and $Market_i \times \mu_t$ are respectively –0.0091 and 0.0052, which also imply a negative total effect on market-oriented FDI. One possible reason for the estimated coefficient of R_{t-1} or μ_t to be negative is that exchange rate movements might exert negative impacts on FDI activity through some other channels, such as the imperfect capital market hypothesis advanced by Froot and Stein (1991). Whereas this paper uses the industry characteristics to demonstrate the importance of diversity of investing motives in investigating the effect of exchange rate movements on the FDI, further research to examine the determinants of their total effects seems warranted.[18]

Our empirical findings indicate that relative wage rates, the exchange rate level, and its volatility have 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.

V. CONCLUSION

This paper theoretically and empirically examines how exchange rate changes influence FDI activity. The real options framework of Dixit (1989a) 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.

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

[18] One possible extension is to use firm-level data and incorporate the effects of firm heterogeneity into the empirical model.

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.

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APPENDIX I

THE DERIVATION OF EQUATIONS (4) AND (7)

This appendix describes the derivation of equations (4) and (7) in Section II of the main text. The derivations of $\partial R_H/\partial k$, $\partial R_H/\partial W_f$, $\partial R_L/\partial k$, and $\partial R_L/\partial W_f$ were deemed obvious, so we have omitted the proof. To save space we use the following results in Dixit (1989a, 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):

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

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

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

According to equation (3) in Section II, differentiating R_H with respect to μ, we next have:

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

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

Since we assume that $\mu < \rho$,[19] 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 II, differentiating R_L with respect to μ, we similarly have

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

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

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

[19] See footnote 7.

Because μ is the growth rate of the exchange rate, we have $\mu > -1$.[20] Therefore, $\partial\psi/\partial\rho < 0$, if $\partial\psi/\partial\rho|_{\mu=-1} \leq 0$ and $\partial^2\psi/\partial\mu\partial\rho < 0$. From equation (A9), we have

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

and

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

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 $\partial\psi/\partial\rho|_{\mu=-1,\sigma^2=\infty} = -2 < 0$ and thus $\partial\psi/\partial\rho|_{\mu=-1} \leq 0$. We have now completed the proof of $\partial R_L/\partial\mu < 0$.

APPENDIX II

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* published by the Investment Commission, Ministry of Economic Affairs, Republic of China (MOEAIC), 2004. China's real GDP is measured in 1995 prices 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 NT\$ per RMB. It is calculated with a nominal exchange rate of NT\$ to US\$, and that of RMB to US\$, and it is deflated with Taiwan's CPI and China's CPI, respectively. These data are compiled from the AREMOS database, Ministry of Education, Republic of China (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

[20] Since an exchange rate, R, has to be positive and μ represents the growth rate of R, thus μ has to be greater than -1; otherwise the value of R will become negative.

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

$$\mu_{Tasy,t} = \frac{1}{T\cdot\Delta}\sum_{j=1}^{T} r_{t-j+1} + \frac{\sigma^2_{Tasy,t}}{2},$$

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

Second, a GARCH process is adopted to estimate the volatility. With data covering the period from January 1989 to December 2002, 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:

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

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

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

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

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 issues, published by MOEAIC.