Chapter 4

The impact of exchange rate movements on Taiwan's Outward FDI into China: Market-seeking versus Export-substituting

1. Introduction

The purpose of this chapter is to employ firm-level data to examine the effect of exchange rate movements on export-substituting FDI versus market-seeking FDI. There are several reasons for the use of firm-level data to reexamine the relationship between exchange rates and FDI: First, due to limitations of the industrial data, the empirical analysis in Chapter 3 does not cover the case of export-substituting FDI. Second, the empirical results with industry-level data might also suffer from aggregation bias to some extent, whereas an analysis with firm-level data will not have the same concern. Third, the real options model developed in Chapter 2 provides hypotheses regarding the optimal timing of FDI. Firm-level panel data have most useful information to deal with this issue.

The remainder of this chapter proceeds as follows. In the following section, the empirical methodology used in this chapter is introduced. Section 3 establishes the empirical model on the basis of the theoretical results in Chapter 2, followed in the subsequent section by a presentation of the data and empirical results. Brief concluding remarks are given in the final section.

2. Empirical methodology

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

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

This chapter adopts Cox's proportional hazard model (Cox (1972, 1975)).[46] One of the advantages about Cox's model is that it imposes the condition of "hazard proportionality" and thus makes the analysis of covariates possible without specifying a hazard function itself. The model treats each sample's hazard rate $h_i(t)$ as a function of a number of covariates and conceptually defines the baseline hazard $h_0(t)$ that is not influenced by any covariate. Based on the hazard proportionality assumption, the model treats the proportion of $h_i(t)$ and $h_0(t)$ as constant. Hence,

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

the proportion is interpreted as a function of covariates.[47]

Hazard rate is defined as the rate at which a firm invests in a foreign country by t given that the firm has stayed in the home country until t. Thus, the hazard function, $h(t \mid \mathrm{x}_i)$, can be expressed as[48]

$$h\left(t \mid \mathrm{x}_{i1}, \mathrm{x}_{2i}(t)\right) = h_0\left(t\right)\exp\left(\beta' \mathrm{x}_{1i} + \alpha' \mathrm{x}_{2i}(t)\right) \tag{4-1}$$

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

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

$$L_p = \prod_{i=1}^{n} \left[\frac{e^{\beta' \mathrm{x}_{1i} + \alpha' \mathrm{x}_{2i}(t)}}{\sum_{j \in \Omega(t_i)} e^{\beta' \mathrm{x}_{1j} + \alpha' \mathrm{x}_{2j}(t)}} \right]^{\delta_i} \tag{4-2}$$

where $\Omega(t_i)$ represents the number of firms that are at risk of experiencing an entry at time t_i, that is, the "risk set"; δ_i is an indicator, its value is 0 if the sample is right-censored, and 1 if the sample is uncensored.[49] The positive (negative) estimators $\hat{\beta}$ and $\hat{\alpha}$ represent the variables have positive (negative) impacts on the occurrence of the event. To solve Equation (4-2), there are three methods to compute the ties[50]: Breslow method, Efron method and Exact discrete method[51]. It turns out that our

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[47] See Box-Steffensmeier and Jones, (2004), Chapters 2 and 4.
[48] See Appendix 4-1 for details.
[49] If firms do not invest in the sample period but may invest in the future, then the sample is referred to as a right-censored sample.
[50] "Ties" occur when two or more firms enter a market at the same observed time.
[51] See Appendix 4-1.

results are not sensitive to which method is used.

Table 4-1. Definition of the explanatory variables and their expected signs

<table>
<tr><th rowspan="2">Explanatory Variable</th><th rowspan="2">Definition</th><th colspan="2">Expected sign</th></tr>
<tr><th>Market-seeking FDI</th><th>Export-substituting FDI</th></tr>
<tr><td>Exchange rate volatility (σ_t)</td><td>Volatility of the real exchange rate</td><td>-</td><td>?</td></tr>
<tr><td>Exchange rate trend (μ_t)</td><td>Trend of the real exchange rates</td><td>?</td><td>?</td></tr>
<tr><td>Exchange rate (R_{t-1})</td><td>One-period lagged real exchange rate of NTD currency against RMB</td><td>+</td><td>-</td></tr>
<tr><td>Relative wage rate ($WAGE_{t-1}$)</td><td>Ratio of China's one-period lagged real wage rate over Taiwan's one-period lagged real wage rate</td><td>?</td><td>-</td></tr>
<tr><td>Marketing intensity (MKT_i)</td><td>Average ratio of marketing expenditures to total sales of the firm over the period 1987-1991★ (%)</td><td>-</td><td>-</td></tr>
<tr><td><u>Control variables</u></td><td></td><td colspan="2"></td></tr>
<tr><td>Profit rate ($PF_{i,t}$)</td><td>Average ratio of profits to total sales of the firm over the period 1987-1991★ (%)</td><td colspan="2">+</td></tr>
<tr><td>Source of funds ($FUND_i$)</td><td>Dummy variable, whose value is 1 for the firms that are provided with funds from parent; 0, otherwise</td><td colspan="2">+</td></tr>
<tr><td>R&D intensity ($R\&D_i$)</td><td>Average ratio of R&D expenditures to total sales of the firm over the period 1987-1991★ (%)</td><td colspan="2">+</td></tr>
<tr><td>Firm size ($SIZE_i$)</td><td rowspan="2">Average sales of the firm over the period 1987-1991★ (billion NTD)</td><td colspan="2">+</td></tr>
<tr><td>Squares of firm size ($SIZE_i$* $SIZE_i$)</td><td colspan="2">-</td></tr>
<tr><td>Capital-labor ratio(KL_i)</td><td>Average ratio of total fixed assets to the number of employees of the firm over the period 1987-1991★ (million NTD per worker)</td><td colspan="2">-</td></tr>
<tr><td>High-technology industry (HT_i)</td><td>Dummy variable, whose value is 1 for the electronics & electric appliances, chemicals and precision instruments industries; 0 otherwise.</td><td colspan="2">?</td></tr>
</table>

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

3. Empirical model

Based on the theoretical framework of Chapter 2 and Equation (4-1), the following empirical model is established:

$$\begin{aligned}\log\left[h(t)/h_0(t)\right] = {} & \alpha_1\sigma_t + \alpha_2 EX_M * \sigma_t + \alpha_3 EX_E * \sigma_t \\ & + \alpha_4 R_{t-1} + \alpha_5 EX_M * R_{t-1} + \alpha_6 EX_E * R_{t-1} \\ & + \alpha_7 \mu_t + \alpha_8 EX_M * \mu_t + \alpha_9 EX_E * \mu_t \\ & + \alpha_{10} WAGE_{t-1} + \alpha_{11} PF_{i,t_i} \\ & + \beta_1 MKT + \beta_2 FUND_i \\ & + \beta_3 R\&D_i + \beta_4 SIZE_i + \beta_5 SIZE_i * SIZE_i \\ & + \beta_6 KL_i + \beta_7 HT_i\end{aligned} \tag{4-3}$$

Here, subscript i represents i^{th} firm and subscripts M and E represent the market-seeking firm and export-substituting firm, respectively. Since Taiwanese firms were not permitted to invest in China until 1987, the dependent variable is defined as the duration from 1987 to the year when the firm invested there. As for independent variables, in addition to the variables suggested in Chapter 2, some are added as explanatory variables in order to control for some important factors that are not considered in our theoretical framework. The definition of these variables and their expected signs are discussed as follows (see also Table 4-1):

σ_t : exchange rate volatility. According the model in Chapter 2, while exchange rate uncertainty tends to deter the FDI activity of market-seeking firms, its impact on export-substituting firms is ambiguous. To test the validity of our theory, we define two dummy variables: 1. EX_M , whose value is 1 for market-seeking firms, and 0 otherwise; 2. EX_E , whose value is 1 for export-substituting firms, and 0 otherwise. Therefore, the expected sign of $(\alpha_1+\alpha_2)$ is negative, and that of $(\alpha_1+\alpha_3)$ is positive (negative) for those export-substituting firms with high (low) risk-aversion.

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

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

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

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

As for the control variables, based on the previous studies,[52] the following variables are used: profits (*PF*), source of funds (*FUND*), R&D intensity (*R&D*), firm's size (*SIZE*), capital-labor ratio (*KL*), and high-tech industry dummy (*HT*). According to the liquidity hypothesis, since the cost of internal funds is viewed by investors to be lower than the costs of external funds,[53] there is a positive relation between a firm's internal cash flows and its investment abroad. The profit rate ($PF_{i,t}$) is used as a proxy of a firm's internal capital, the expected sign of its coefficient is positive. In addition, if the parent company of an investing firm can provide necessary funds, it suggests that the firm is more unlikely to face financial constrain, and thus it will be more likely to enter foreign markets earlier. We create a dummy variable $FUND_i$, whose value is 1 if the parent company provides the necessary funds and 0 otherwise. We expect the sign of its coefficient to be positive.

The internalization hypothesis indicates that due to high transaction costs of intangible assets, an investing firm with superior knowledge and management expertise will choose to set up a subsidiary rather than simply licensing a foreign firm to produce the product. R&D intensity variable ($R\&D_i$) is used as a measure of the investing firm's intangible asset. The expected sign of this variable is positive.[54] In addition, Horst (1972) argues that a firm's success at home will be highly correlated with its success abroad, since both are the result of the same technological and marketing capabilities. Hence, lager firms are more likely to invest abroad than smaller firms. The sales of a firm ($SIZE_i$) are used to measure its size and its expected

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

sign is positive. However, as pointed out by Tan et al. (2002), very large Taiwanese firms suffer more from institutional pressures from Taiwan's government to not invest into China due to hostility across the Taiwan Strait. Thus, the effect of the firm's size should have an inverse U-shape. That is, the expected sign of the coefficient of $SIZE_i$ is positive but that of $SIZE_i*SIZE_i$ is negative.

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

4. The data and empirical results

4.1 The data

The data on the dependent variable used in this chapter are compiled from the "*Survey on Taiwanese Firms in Mainland China*", published by Taiwan's Investment Commission, Ministry of Economic Affairs (MOEAIC) in 2003 and 2004. It investigated all firms which invested in China for more than one year. This chapter chooses 198 listed companies on Taiwan Stock Market from the sample of the survey. Taiwan Economic Journal (TEJ) database indicates that among 1,145 available listed companies on Taiwan's Stock Market, 672 companies invested in China before 2002. Thus, our sample firms account for 29.5% of all Taiwanese firms investing into China. To avoid the problem of sample selection bias, we use a uniform distribution to randomly choose 139 companies from those listed firms that had not invested in China before 2002. Because these companies might have invested in China after 2002, they are treated as right-censored samples. Therefore, our final sample consists of 337 firms.

Taiwan government prohibited domestic firms from having any trade or investment relationship with China before 1987. These barriers in trade or investment were removed or lowered starting in 1987. We therefore analyze the timing of Taiwanese firms' entry into China during the period from 1987 to 2002. In other words, Taiwanese firms enter the risk set of entry from 1987, but there are 36 firms that were set up after 1987, and thus the risk set of these firms begins from the years of their establishment. The entry years are obtained from the government's official survey data. Figure 4-1 shows the distribution of entry years. The number of entries has increased considerably from 1993, reaching a peak in 2000.

As mentioned above, in order to test the validity of theoretical prediction, two dummy variables EX_M and EX_E are created. We separate the sample firms into three groups, according to their pre-FDI export ratios: market-seeking firms (firms with zero exports), export-substituting firms (firms with export ratios more than 60%), and other firms. The definition of these two variables are accordingly: (1) market-seeking firm dummy, EX_M, taking a value 1 for a firm with zero exports if the sales of the firm's subsidiary account for more than 80% of its total sale in China, and 0 otherwise;

(2) export-substituting firm dummy, EX_E, taking a value 1 for a firm with a export ratio greater than 0.6 if the sales of its subsidiary account for more than 80% of the subsidiary's total sale in China, and 0 otherwise. According to these criteria, we have 23 market-seeking firms and 22 export-substituting firms in our sample.[55]

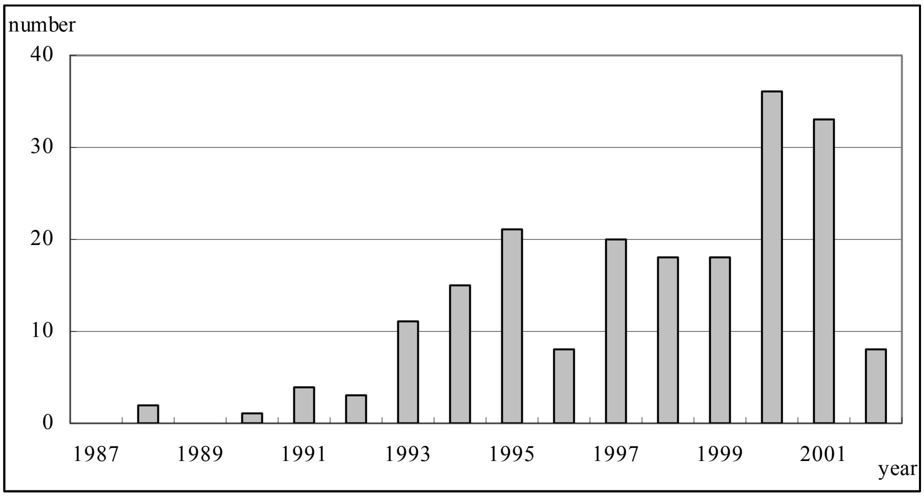

Figure 4-1. Entry years of sample firms

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

[55] To test the robustness of our empirical results, we have relaxed our criteria about investing firms by including those firms with sales of its subsidiary accounting for more than 50% of the subsidiary's total sales in China. We find that the empirical results are basically the same.

persistent behavior.[56] See Appendix 4-2 for details about the calculation of these measures.[57]

Table 4-2 summarizes the distribution of the sample firms by industry. The electronics and electric industries account for significant shares of all sample firms as well as investing firms. Both shares are around 40%. Furthermore, most of export-substituting firms belong to electronic and electric appliances industries, but by contrast, most of market-seeking firms belong to services and food & beverage industries. It is worth noting that the export ratios of the sample firms scatter widely with a standard deviation of 30.8%, which allows us to separate our sample firms into three groups so as to test the validity of our theory. Summary statistics of these variables are summarized in Table 4-3.

Table 4-2. Distribution of sample firms by industry

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

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

[56] The measure of Tsay (2002) belongs to unconditional variance, and the measure of GARCH belongs to conditional variance.
[57] These two measures are the same as the measures in Chapter 3.

Table 4-3. Summary statistics

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

4.2 Empirical results

Table 4-4 summarizes the estimation results of the empirical model.[58] The regression equations reported in columns 1 and 3 are our benchmark case, in which the dummy variables EX_M and EX_E that control for investing motives are not considered. In columns 2 and 4 we introduce these two dummy variables in order to test the validity of our theory.

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

The effect of real exchange rate volatility on market-seeking FDI, as shown in the joint test of ($\alpha_1 + \alpha_2$), is significantly negative, while its effect on export-substituting FDI, as shown in the joint test of ($\alpha_1 + \alpha_3$), is significantly positive. As for the effect of real exchange rate, whereas its effect on market-seeking

[58] The estimation in Table 4-4 uses the method of Efron.

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

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

Table 4-4. The estimation of the determinants of the timing of FDI

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

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

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

$$\%\Delta h(t) = \frac{e^{\beta(x_i = X_1)} - e^{\beta(x_i = \bar{X})}}{e^{\beta(x_i = \bar{X})}} \times 100 \text{,}^{59} \qquad (4\text{-}4)$$

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

Tables 4-5 and 4-6 summarize the estimate results about the magnitude of the covariates' effect on the hazard ratio. They reveal that the most important determinant of Taiwanese investment into China is the relative wage rate. The probability of Taiwanese firm's entry increases by about 50% when relative wage rate raises 10%. As for the exchange rate variables, the exchange rate level seems to have the largest effect on the hazard of entry occurrence. A 10% depreciation of NTD to RMB tends to increase the probability of the occurrence of market-seeking FDI by 19% while it may decrease the probability of the occurrence of export-substituting FDI by 11%. By contrast, a 10% increase in exchange rate volatility tends to increase the probability of export-substituting FDI by 13% while it may decrease the probability of market-seeking FDI by 8%. Other covariates, (e.g., exchange rate trend, marketing intensity, profit rate, R&D intensity, firm's size, and capital labor ratio), only have small influences on the entry decision. It also indicates that compared to the case when *FUND*=0, the probability of a firm's entry is about 2.13 times greater if its parent company can fund the investment.

It is worth noting that the overall effect of exchange rate volatility in this chapter

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

seems different from the estimation in Chapter 3. One possible reason is that the sample firms in this chapter are listed companies in Taiwan's Stock Market, and these companies have higher ability to hedge the exchange rate uncertainty. In contrast, most of the sample firms in Chapter 3 belong to small and middle corporations. Hence, an increase in exchange rate volatility may have largely negative effect on investing decision.

Table 4-5. The effect of covariate changes on hazard ratio: Tsay (2002)

Covariates	Mean	Increase 10% from mean	Estimated Coefficient	% change $h(t)$
Continuous variables				
$\sigma_t(\alpha_1)$:*O*	0.1761	0.1937	5.2413	9.67
$\sigma_t(\alpha_1+\alpha_2)$:*M*	0.1761	0.1937	-4.8815	-8.24
$\sigma_t(\alpha_1+\alpha_3)$:*E*	0.1761	0.1937	7.0129	13.14
$R_{t-1}(\alpha_4)$:*O*	3.6895	4.0585	-0.2342	-8.28
$R_{t-1}(\alpha_4+\alpha_5)$:*M*	3.6895	4.0585	0.4678	18.84
$R_{t-1}(\alpha_4+\alpha_6)$:*E*	3.6895	4.0585	-0.3266	-11.35
$\mu_t(\alpha_7)$:*O*	-0.0275	-0.0248	-0.3465	-0.10
$\mu_t(\alpha_7+\alpha_8)$:*M*	-0.0275	-0.0248	3.5594	0.98
$\mu_t(\alpha_7+\alpha_9)$:*E*	-0.0275	-0.0248	1.6886	0.47
$WAGE_{t-1}(\alpha_{10})$	0.0648	0.0713	-110.91	-51.26
$MKT_i(\beta_1)$	0.0660	0.0726	-3.2747	-2.14
$PF_{i,t}(\alpha_{11})$	0.0510	0.0561	0.0108	0.01
$R\&D_i(\beta_3)$	0.0080	0.0088	0.0954	0.01
$SIZE_i(\beta_4)$	1.9198	2.1118	0.0914	1.77
$KL_i(\beta_6)$	2.5517	2.8069	-0.0926	-2.34
Dummy variables				
$FUND_i(\beta_2)$	0	1	0.7554	112.85
$HT_i(\beta_7)$	0	1	-0.6624	-48.44

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

Table 4-6. The effect of covariate changes on hazard ratio: GARCH (1,1)

Covariates	Mean	Increase 10% from mean	Estimated Coefficient	change in $h(t)$ (%)
<u>Continuous variables</u>				
$\sigma_t(\alpha_1)$:O	0.0378	0.0416	27.29	10.87
$\sigma_t(\alpha_1+\alpha_2)$:$M$	0.0378	0.0416	-22.30	-8.08
$\sigma_t(\alpha_1+\alpha_3)$:$E$	0.0378	0.0416	33.15	13.35
$R_{t-1}(\alpha_4)$:O	3.6895	4.0585	-0.2012	-7.15
$R_{t-1}(\alpha_4+\alpha_5)$:$M$	3.6895	4.0585	0.4564	18.34
$R_{t-1}(\alpha_4+\alpha_6)$:$E$	3.6895	4.0585	-0.3083	-10.75
$\mu_t(\alpha_7)$:O	0.0012	0.0013	-9.9318	-0.12
$\mu_t(\alpha_7+\alpha_8)$:M	0.0012	0.0013	82.98	1.00
$\mu_t(\alpha_7+\alpha_9)$:E	0.0012	0.0013	43.99	0.53
$WAGE_{t-1}(\alpha_{10})$	0.0648	0.0713	-112.02	-51.61
$MKT_i(\beta_1)$	0.0660	0.0726	-3.3328	-2.18
$PF_{i,t}(\alpha_{11})$	0.0510	0.0561	0.0107	0.01
$R\&D_i(\beta_3)$	0.0080	0.0088	0.0991	0.01
$SIZE_i(\beta_4)$	1.9198	2.1118	0.0935	1.81
$KL_i(\beta_6)$	2.5517	2.8069	-0.0924	-2.33
<u>Dummy variables</u>				
$FUND_i(\beta_2)$	0	1	0.7545	112.65
$HT_i(\beta_7)$	0	1	-0.6644	-48.54

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

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

5. Conclusion

This chapter empirically examines how exchange rate uncertainty influences the timing of FDI. Firm-level data on Taiwanese firm's outward FDI into China over the period between 1987 and 2002 are employed to test the validity of the theoretical results in Chapter 2. The empirical findings indicate that real exchange rate movements have had a significant impact on Taiwanese firms' investment into China. In general, the empirical results are consistent with the prediction of the theory. That is, while exchange rate volatilities of RMB to NTD have had delayed the Taiwanese firm's FDI into China of a market-seeking firm, it actually accelerate the FDI activity of an export-substituting firm. This chapter suggests that the relationship between exchange rate uncertainty and FDI, and the relationship between exchange rate level and FDI are crucially dependent on the motives of the investing firms. Hence, it is essential to consider this factor in an empirical model so that the testing results are free from aggregation bias.

Appendix 4-1. Cox Model [60]

Table 4A-1. Variable definition

Variable	Description
T	survival time
$f(t)$	unconditional failure rate; $f(t) = \lim_{\Delta t \to 0} \frac{\Pr(t \le T \le t + \Delta t)}{\Delta t}$
$F(t)$	cumulative distribution function; $F(t) = \int_0^t f(u)du = \Pr(T \le t)$
$S(t)$	survivor function; $S(t) = 1 - F(t)$
$h(t)$	hazard function (hazard rate); $h(t) = \frac{f(t)}{S(t)} = \lim_{\Delta t \to 0} \frac{\Pr(t \le T \le t + \Delta t \mid T \ge t)}{\Delta t}$
$H_0(t)$	cumulative hazard function; $H_0(t) = \int_0^t h(u)du$
x	explanatory variables
β	parameters
$h_0(t)$	baseline hazard function
$\Omega(t_i)$	risk set at time t_i
n	observations
K	distinct entry times
δ_i	indicator; $\delta_i = 0$ if the sample is right-censored; $\delta_i = 1$ if the sample is uncensored.
L_1	partial likelihood function
D_i	set of subjects failed at time t_i
d_i	number of failures at time t_i
S_i	the sum of covariates for the set D_i; $S_i = \sum_{l \in D_i} x_l$

The premise of the Cox model is to estimate the impact of the covariates on the hazard rate, without specifying the distribution of the duration dependency. That is, the baseline hazard rate is not directly estimated. The Cox model is named after the important statistician who derived the model: Sir David Cox. In the 30 plus years

[60] The contents of this Appendix are summarized from Box-Steffensmeier and Jones (2004), Lawless (2003), and Collett (1994).

since Cox's pioneering work, the Cox model has become the workhorse of survival analysis in many, many disciplines.

In Cox model, the hazard rate is given by

$$h_i(t) = h_0(t)\exp(x'\beta) . \qquad (4A\text{-}1)$$

where $h_0(t)$ is the baseline hazard function; *i* represents the sample; and *x* represents the covariates. Since

$$h(t) = \frac{f(t)}{S(t)} = -\frac{S'(t)}{S(t)} = -\frac{d[\ln S(t)]}{dt},$$

it can be shown that

$$\ln S(t) = -\int_0^t h(u)du = -\int_0^t h_0(u)\exp(x'\beta)du = \exp(x'\beta)\left[-\int_0^t h_0(u)du\right],$$

or

$$S(t) = S_0(t)\exp\left[\exp(x'\beta)\right] = \exp\left[-\exp(x'\beta)H_0(t)\right]. \qquad (4A\text{-}2)$$

Suppose that we have a data set with *n* observations, *K* distinct failure (event) times, and *n-K* censoring times. Cox estimation first proceeds by sorting the ordered failure times, such that

$$t_1 < t_2 < ... < t_K ,$$

where t_i denotes the failure time for the i^{th} individual. Define $\Omega(t)$ to be the risk set at t^-, and $\Omega(t_i)$ to be the risk set at the time just prior to the i^{th} failure. Then,

$$\Omega(t_1) \supset \Omega(t_2) \supset ... \supset \Omega(t_K)$$

In addition, for censored cases, we define δ_i to be 0 if the case is right-censored, and 1 if the case is uncensored. Now, the ordered event times are modeled as a function of covariates, *x*. According to Equations (4A-1) and (4A-2), the likelihood is

$$
\begin{aligned}
L(\beta,h_0) &= \prod_{j=1}^{n} f(t_j \mid x_j)^{\delta_j} S(t_j \mid x_j)^{1-\delta_j} \\
&= \prod_{j=1}^{n} h(t_j \mid x_j)^{\delta_j} S(t_j \mid x_j) \\
&= \prod_{j=1}^{n} \left[h_0(t_j)\exp(x_j'\beta) \right]^{\delta_j} \exp\left[-\exp(x_j'\beta) H_0(t_j) \right]
\end{aligned}
\tag{4A-3}
$$

The basic idea from Cox is to break $L(\beta,h_0)$ into two parts: one part is a function of β only. That is, $L(\beta,h_0) = L_1(\beta)\cdot L_2(\beta,h_0)$. The solution of likelihood function is as follows.

1. No ties between failure times

If there are no ties between failure times, then Equation (4A-3) can be rewritten as

$$
\begin{aligned}
L(\beta,h_0) &= \prod_{j=1}^{K} h_0(t_j)\exp(x_j'\beta) \prod_{j=1}^{n} \exp\left[-\exp(x_j'\beta) H_0(t_j) \right] \\
&= \prod_{j=1}^{K} \frac{\exp(x_j'\beta)}{\sum_{l\in\Omega(t_i)} \exp(x_l'\beta)} , \\
&\times \prod_{j=1}^{K} h_0(t_j) \sum_{l\in\Omega(t_i)} \exp(x_l'\beta) \prod_{j=1}^{n} \exp\left[-\exp(x_j'\beta) H_0(t_j) \right]
\end{aligned}
$$

or

$$
L(\beta,h_0) = L_1(\beta)\cdot L_2(\beta,h_0) , \tag{4A-4}
$$

where

$$
L_1(\beta) = \prod_{j=1}^{K} \frac{\exp(x_j'\beta)}{\sum_{l\in\Omega(t_i)} \exp(x_l'\beta)} , \tag{4A-5}
$$

and

$$
L_2(\beta,h_0) = \prod_{j=1}^{K} h_0(t_j) \sum_{l\in\Omega(t_i)} \exp(x_l'\beta) \prod_{j=1}^{n} \exp\left[-\exp(x_j'\beta) H_0(t_j) \right] .
$$

Cox (1972) suggests that we can use $L_1(\beta)$ to estimate β. However, $L_1(\beta)$ is not in general the PDF of a subset of the data. Hence, it is called a partial likelihood function. For simplicity, we ignore to figure out $L_2(\beta, h_0)$ further. $L_1(\beta)$ is the marginal distribution of rank statistic when there are no ties. Thus, $L_1(\beta)$ is a real likelihood for the rank statistic when there are no ties. Therefore, the partial likelihood function is solely based on the ordered duration times, and not on the length of the interval between duration times.

Maximization of Equation (4A-5) with respect to β yields an estimator $\hat{\beta}$ which it is called PMLE of β. According to $L_1(\beta)$, we could calculate Fisher information and find the asymptotic distribution of $\hat{\beta}$. Since there is some information about β in the discarded proportion of the entire likelihood, the resulting estimates are not fully efficient. However, the loss of efficiency is quite small.[61] The properties of PMLE of β are consistent and asymptotically normal. In addition, it depends only on the ranks of the event times, not their numerical values. This implies that any monotonic transformation of the event times will leave the coefficient estimates unchanged (e.g., taking log, square root, adding a constant…etc).

2. Partial likelihood when ties present

If subjects 1 and 2 are tied at t_1 due to sampling, then actual value T_1 and T_2 are different. However, the observed values are the same. In other words, we don't know whether $T_1<T_2$ or $T_1>T_2$. Therefore, there are three main methods to solve the problem of ties, which are introduced as follows.

[61] Efron (1977) and Oakes (1977) have compared the Fisher information in the partial likelihood to the Fisher information in the full likelihood for a variety of models. The efficiency is usually at least 90%, and in rare case achieves 100%.

2.1 Breslow (1974)

The Breslow method assumes that the size of the risk set is the same, regardless of which event occurred first. Thus, the partial likelihood function can be rewritten as

$$L_B(\beta)=\prod_{i=1}^{K}\prod_{j\in D_i}\frac{\exp(x_j'\beta)}{\sum_{l\in\Omega(t_i)}\exp(x_l'\beta)}=\prod_{i=1}^{K}\frac{\exp(S_i'\beta)}{\left[\sum_{l\in\Omega(t_i)}\exp(x_l'\beta)\right]^{d_i}} \qquad \text{(4A-6)}$$

The Breslow approximation has proven to be adequate when the number of tied events is small at any given period. However, as the number of tied cases increases, the size of the risk set at each period gets very large and the approximation is less precise.

2.2 Efron (1977)

The Efron method accounts for how the risk set changes depending on the sequencing of tied events. The partial likelihood function is

$$L_E(\beta)=\prod_{i=1}^{K}\frac{\exp(S_i'\beta)}{\prod_{j=1}^{d_i}\left[\sum_{l\in\Omega(t_i)}\exp(x_l'\beta)-\frac{j-1}{d_i}\sum_{m\in D_i}\exp(x_m'\beta)\right]} \qquad \text{(4A-7)}$$

Since this method accounts for the differing composition of the risk set at t_i, the approximation is more accurate than the Breslow method.

2.3 The exact method

2.3.1 Continuous time version: Peto (1972)

This method considers all possible ordering at each tied failure. So if there are d_i failures at t_i, then consider all d_i! possible orderings. The partial likelihood function becomes

$$L_P(\beta) = \prod_{i=1}^{K} \frac{\exp(S_i'\beta)}{\sum_{j=1}^{d_i!} \prod_{r=1}^{d_i} \sum_{l \in \Omega(q_{jr})} \exp(x_l'\beta)} \qquad \text{(4A-8)}$$

where q_{jr} is the failed case in time t_i; $\Omega(q_{jr}) = \Omega(t_i) - \{q_{j1}, q_{j2}, ..., q_{j,r-1}\}$.

2.3.2 Discrete time version: Cox (1972)

This method proceeds by assuming that the events really do occur at the same time. The partial likelihood function is

$$L_P(\beta) = \prod_{i=1}^{K} \frac{\exp(S_i'\beta)}{\sum_{q \in Q_i} \exp(S_q^{*\prime}\beta)} \qquad \text{(4A-9)}$$

where Q_i is the set of all possible d_i elements in $\Omega(t_i)$; $q = (q_1, ..., q_{d_i}) \in Q_i$, $S_q^* = \sum_{j=1}^{d_i} x_{qj}$. For example, $\Omega(t_i) = \{1,2,3,4\}$, d_i=2, Q_i={(1,2), (1,3), (1,4), (2,3), (2,4), (3,4)}. Actually, this approximation is equivalent to a conditional logit model.[62]

[62] See Allison (1982) for proof.

Appendix 4-2. Data Description

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

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

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

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

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

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

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

where $\Delta \ln R_t$ is the first difference of the real exchange rate; and h_t is the conditional variance of the error term u_t. The numbers in parentheses are t-statistics.

Thus, μ_{GARCH} and σ_{GARCH} are defined respectively as

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

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

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