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ARTICLE INFO	Yi-Chein Chiang and Yi-Chan Lin (2008). Exchange rate exposures of Taiwanese firms. *Investment Management and Financial Innovations*, *5*(4-1)
RELEASED ON	Thursday, 15 January 2009
JOURNAL	"Investment Management and Financial Innovations"
FOUNDER	LLC “Consulting Publishing Company “Business Perspectives”

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
0	**0**	**0**

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Exchange rate exposures of Taiwanese firms

Abstract

This study aims to investigate whether the stock returns of Taiwanese firms are exposed to exchange rate risks. Our results show that only a small percentage of Taiwanese firms are exposed symmetrically, but a larger percentage of them are exposed asymmetrically no matter in the short or longer time horizons. The traditional symmetric measures may underestimate exchange rate exposure. In addition, this underestimation is associated with wrong direction in the long run due to the J-curve effect of Taiwanese firms. Only when considering potential asymmetric exposure components can firms' financial exposures be estimated and hedged properly.

Keywords: exchange rate exposures, exposure puzzle, asymmetric exposures, J-curve effect.
JEL Classification: F31, G39.

Introduction

It is often assumed that multinational firms exhibit foreign exchange rate exposures due to their international activities. However, previous studies have found weak correlation between changes in exchange rates and firm values (Jorion, 1990; Bodnar and Gentry, 1993; Amihud, 1994, Choi and Prassad, 1995; Dukas, Fatemi, and Tavakkol, 1996; Martin, Madura, and Akhithegbe, 1999), a finding which has been perceived as the "exposure puzzle."

Several researchers attempt to determine the cause of the weak evidence of exchange rate exposure. Bartov and Bodnar (1994) investigate the possibility that the inclusion of lagged changes of the exchange rate. Chow, Lee, and Solt (1997a, b) argue that failure to discover exchange rate exposure is because of the fact that exchange rates affect cash flows over longer periods. Another issue addressed in previous literature mentions financial and operational hedging as a possible explanation (Geczy, Minton and Schrand, 1997; He and Ng, 1998; Makar, Debruin, and Huffman, 1999; Allayannis and Ofek, 2001; Crabb, 2002; Nguyen and Faff, 2003). The empirical evidence that exchange rates affect a firm's value is still weak and requires more research.

Existing studies investigate almost exclusively symmetric foreign exchange rate exposures[1], which implicitly assumes that firms act as passive exporters and/or importers. However, there are some firm behaviors resulting in asymmetric exposures, such as pricing-to-market (Krugman, 1987; Froot and Klemperer, 1989; Marston, 1990; Knetter, 1994; Goldberg, 1995), hysteresis (Ljungqvist, 1994; Christophe, 1997) and asymmetric financial and operational hedging (Ware and Winter, 1988; Kanas, 1997; Miller and Reuer, 1998; Chatterjee, Lubatkin, and Schulze, 1999).

We argue that the lack of consideration of asymmetric exposures is one of the reasons for the exposure puzzle, and the exposure puzzle, to some extent, may be due to the estimating models. Specifically, if there is asymmetric exposure and the traditional symmetric model (linear model) is used to detect exchange rate exposure, it's very likely to find weak correlation between exchange rate changes and firm values, and results in underestimation of exchange rate exposure and even the wrong direction of exposure.

If the risk profile is asymmetric, instruments with asymmetric profile (currency options) should be preferred to instruments with symmetric profile (forwards, futures) (Ware and Winter, 1988; Miller and Reuer, 1998). In addition, profit-seeking individuals and portfolio managers who invest in stocks, financial engineers who design financial instruments, and governments that seek smooth functioning of financial markets and resultant economic development should reconsider the context of those asymmetries (Jayasinghe and Premaratne, 2004). To date, Miller and Reuer (1998), Di Iorio and Faff (2000), Koutmos and Martin (2003) and Jayasinghe and Premaratne (2004) are the only studies that have attempted to model asymmetric responses to currency appreciations and depreciations. In their work, asymmetric exposures have been proven in some firms and industries.

Most countries have adopted floating exchange rate system since 1973. The exchange rate changes are volatile ever since, and foreign exchange rate exposures of firms and industries are assumed to be large. Firms in a small open economy, including Taiwan, tend to rely heavily on the international trade, and are always expected to be more sensitive to the exchange rate changes.

Using monthly data of the period 1996 to 2005, this study investigates whether the stock returns of Taiwanese firms are exposed to exchange rate risks. Our results show that only a small percentage of Taiwanese firms are exposed symmetrically, but a larger

This work was supported by the National Science Council, Taiwan, R.O.C., under Grant NSC 97-2410-H-035-011.

[1] The assumption of symmetry means that no difference exists between the risk effects of currency appreciation and depreciation.

percentage of them are exposed asymmetrically no matter in the short or longer time horizons. The traditional symmetric measures may underestimate exchange rate exposure. In addition, this underestimation is associated with wrong direction in the long run due to the J-curve effect of Taiwanese firms.

The paper is organized as follows. Section 1 describes how asymmetric exchange rate exposures could exist in the context of pricing-to-market, hysteresis, and asymmetric hedging. Section 2 describes the sample and data source. Section 3 shows the methodologies and the results. Finally, the last section concludes the paper.

1. Asymmetric response to exchange rate movements

The view that exchange rate exposure is symmetric between currency appreciations and depreciations is valid only if the firms act as passive exporters and/or importers. In fact, firms may attempt to exploit opportunities and avoid adverse effects to exchange rate changes (Jayasinghe and Premaratne, 2004).

There are a few behavioral characteristics of firms with which one can explain the asymmetric nature of exchange rate exposure.

1.1. Pricing-to-market. Pricing to market (PTM) essentially involves adjusting export prices based on the degree of competition in foreign markets. A firm's profits would increase to a lesser degree during depreciation periods than decrease in appreciation periods. Several studies such as Krugman (1987), Froot and Klemperer (1989), Marston (1990), Knetter (1994), and Goldberg (1995), have developed models to explain pricing-to-market behavior of firms.

PTM essentially implies that firms can flexibly adjust export prices based on the intention of (i) market share objective and (ii) sales volume constraints (Knetter, 1994). When the domestic currency appreciates, exporters may not increase foreign prices due to their market share objective. Exporters with market share objective maintain rather than attempt to increase their profits, thus they pass the benefits of domestic currency depreciation to foreign prices by reducing foreign prices, so that sales volumes and market shares grow. Thus, their profits would increase to a lesser degree when the host currency depreciates, versus decreasing when the host currency appreciates.

Firms also adjust their sales prices under the consideration of sales volume constraints. Because the constraints eliminate the possibility of increasing sales volume with domestic currency depreciations, exporters increase foreign prices to clear the market. However, the constraints may disappear with domestic currency appreciations and result in a lessened degree of a firm's PTM behavior. As a result, firm's profits decrease less when domestic currency appreciates than they would increase when domestic currency depreciates.

1.2. Hysteresis. Hysteresis pertains to effects that persist after the original causes of the effects no longer exist. An exporter's profits expressed in domestic currency would increase with a foreign currency appreciation and decrease with a foreign currency depreciation. However, the decrease could be relatively larger than the increase due to hysteresis.

One may presume that if domestic currency persists relatively weak for a longer period of time, new exporters may enter the market to take advantage of it. As a result, the profits of existing exporters may not increase the degree that would occur with no new entrants. In contrast, exporters may quit the market once domestic currency appreciates. However, hysteresis drives firms to maintain high-sunk cost investments, such as entry costs, when the domestic currency appreciates (Ljungqvist, 1994; Christophe, 1997). Therefore, exporters may remain even to the point of suffering operating losses and the cash flows of exporters (new and existing exporters) are likely to decrease. That is, the reduction in profits during appreciations is larger than the increase in profits during depreciations.

1.3. Hedging with financial and real options. Currency options are asymmetric instruments that can be used to provide downside protection with the opportunity to exploit upside potential. Firms with net long positions (i.e. net exporters with foreign currency receivables) may be inclined to hedge against domestic currency appreciations yet remain unhedged against domestic currency depreciations. Alternatively, firms with net short positions (i.e. net importers with foreign currency payables) may be inclined to hedge against domestic currency depreciations yet remain unhedged against domestic currency appreciations (Ware and Winter, 1988; Kanas, 1997).

Real option theory suggests that operational flexibility allows the firm to selectively exploit currency movement to its advantage while sheltering the firm during periods when exposure would adversely affect the firm's value. Exchange rate changes can be avoided or exploited by shifting sourcing, production and sales across currency borders (Dixit and Pindyck, 1994; Miller and Reuer, 1998; Chatterjee, Lubatkin, and Schulze, 1999).

Actively using financial or real options mean that exchange rate exposures would be larger to beneficial exchange rate changes than to adverse ones.

2. Sample selection and data description

We select non-financial firms listed on the Taiwan Stock Exchange Corporation (TSEC). Following Jorion (1990), we include only firms whose foreign sales ratio is more than 10 percent. There are 141 firms in our final sample. Our sample periods cover 1996 to 2005.

The data of stock returns (R_{it}), market portfolio returns (R_{mt}) and exchange rate returns (R_{st}) are obtained from the Web site of the *Taiwan Economic Journal* (TEJ). The market portfolio, TAIEX, is a value-weighted index of Taiwan that involves all currently listed common stocks[1]. The exchange rate used here is the U.S. Dollar (USD) in terms of the New Taiwan Dollar (NTD). The choice of NTD/USD is supported by the following reasons. First, Taiwan is a small and export-oriented economy, and the United States is one of the largest trade partners of Taiwan. Second, since the USD is a leading vehicle currency, prices of tradable goods are often denominated in the USD, no matter which countries Taiwanese firms trade with (Chiao, Hung and Nwanna, 2001). Third, the correlation coefficient between NTD/USD and the effective exchange rate[2] for the NTD is about 90%. The effects of NTD/USD seem to dominate other exchange rates.

Table 1 presents the summary statistics of monthly returns of the market portfolio and the exchange rate. The Jarque-Bera test shows that both variables are normally distributed. The Ljung-Box Q(5) and Q(10) statistics indicate that no significant autocorrelation exists. The Ljung-Box Q^2 (5) and Q^2 (10) statistics indicate that there is no significant autocorrelation in the squared return series and the existence of possible volatility clustering. Unit-root test is performed with the augmented Dickey-Fuller (ADF) test, showing that both variables are stationary.

Table 1. Descriptive statistics: monthly returns of market portfolio (R_{mt}) and exchange rate (R_{st})

	R_{mt}	R_{st}
Mean	0.0019	0.0016
Maximum	0.2252	0.0730
Minimum	-0.2150	-0.0457
Std. dev.	0.0816	0.0143
Skewness	0.0172	0.9744
Kurtosis	3.2857	3.4030
Jarque-Bera	0.4141	1.6495
Observations	120	120
L-B Q (5)	6.2658	2.3130
L-B Q (10)	15.209	13.597
L-B Q^2 (5)	9.2601	15.499
L-B Q^2 (10)	13.313	13.617
ADF (n)	-10.553(0)***	-7.4910(0)***

Notes: 1. Jarque-Bera is a test statistic for testing whether the series is normally distributed. 2. L-B Q (k) and L-B Q^2 (k) are Ljunng-box Q-statistics used to test for serial correlation and k is the length of lag. 3. ADF (n) is unit root test. 4. *, **, *** indicate the estimates are significant at the level of 0.1, 0.05, and 0.01, respectively.

3. Methodologies and results

We estimate exchange rate exposures of 141 Taiwanese firms using both the traditional symmetric model and the asymmetric model.

3.1. Traditional symmetric model. Following Jorion (1990) and other existing literature, time-series regressions for each firm are estimated using the traditional symmetric model as the equation (1). Standard errors are corrected for autocorrelation and heteroscedasticity using the Newey-West method.

$$R_{it} = \beta_0 + \beta_1 R_{mt} + \beta_2 R_{st} + \varepsilon_{it}, \quad (1)$$

where R_{it} is the stock return of firm *i* in period *t*; R_{mt} is the return of market portfolio in period *t*[3]; R_{st} is the exchange rate change in period *t*; ε_{it} is the error term in period *t*; β_0, β_1, and β_2 are regression parameters. An appreciation (depreciation) of the New Taiwan Dollar (NTD) will produce a negative (positive) value for R_{st}. β_2 measures exposure to exchange rate movements. A statistically significant β_2 implies that exchange rate changes affect stock returns. Firms are classified as "net exporters" with positive β_2 and "net importers" with negative β_2.

Of the 141 firms, only 13 have a significant exposure to exchange rate movements under the significance level of 0.10, as shown in Table 2. Similar to literature, our empirical results provide weak evidence of exchange rate exposures.

[1] We use TAIEX as the market portfolio, due to the fact that it is the only equity index of listed firms in Taiwan. There is no equally weighted equity index in Taiwan.

[2] An effective exchange rate is a measure of the weighted-average value of a currency relative to two or more other currencies.

[3] The market portfolio return is used not only to control for macroeconomic influences but also to dramatically reduce the residual variance of the regression (Bodnar and Wong, 2003).

Table 2. Results of estimating exchange rate exposures (traditional symmetric model)

	$\beta_2 > 0$	$\beta_2 < 0$	Row total
No. of coefficient	54	87	141
No. of significance	4	9	13
Percentage	7.40%	10.34%	9.21%

Note: This table provides results of the traditional symmetric model: $R_{it} = \beta_0 + \beta_1 R_{mt} + \beta_2 R_{st} + \varepsilon_{it}$, where R_{it} is the stock return of firm *i* in period *t*; R_{mt} is the return of market portfolio in period *t*; R_{st} is the exchange rate change in period *t*; ε_{it} is the error term in period *t*; β_0, β_1, and β_2 are regression parameters.

3.2. Asymmetric model. In order to assess possible asymmetries in firms' foreign rate exposures, equation (2) was estimated for each firm.

$$R_{it} = \beta_0 + \beta_1 R_{mt} + \beta_2 R_{st} + \beta_3 D_{it} R_{st} + \varepsilon_{,it}$$

$$D_{it} = \begin{cases} 1 & if \quad R_{st} \le 0 \\ 0 & if \quad R_{st} > 0 \end{cases}, \qquad (2)$$

A test for asymmetry is equivalent to a test that β_3 is statistically significant. For a given value of the market portfolio, the response of R_{it} will be equal to β_2 if $R_{st} > 0$ and $\beta_2 + \beta_3$ if $R_{st} \le 0$.

After assessing the sign and significance of exposure coefficients for each firms, we construct matrices as Table 3, indicating the relative frequency of firms displaying the nine possible exposure profiles[1].

Table 3. Possible combinations of exchange rate exposures

	$\beta_2 > 0$	$\beta_2 = 0$	$B_2 < 0$
$\beta_3 > 0$	(I) PTM with MSO or hysteresis (net exporters)	(IV) PTM with MSO or hysteresis (net exporters)	(VII) PTM with MSO (net importers)
$\beta_3 = 0$	(II) Symmetric exposure (net exporters)	(V) No exposure (net exporters or net importers)	(VIII) Symmetric exposure (net importers)
$\beta_3 < 0$	(III) Asymmetric hedging or PTM with VC (net exporters)	(VI) Asymmetric hedging or PTM with VC (net importers)	(IX) Asymmetric hedging (net importers)

Notes: Pricing-to-market (PTM); market share objective (MSO); Volume constraints (VC).

Table 4 provides evidence that firms are rarely exposed symmetrically to currency appreciations and depreciations ($\beta_2 \ne 0$ and β_3=0). Of the 141 firms, only 8 have symmetric significant exposures to exchange rate movements (cells (II) + (VIII)). Furthermore, 18 of them are exposed asymmetrically (cells (I) + (III) + (IV) + (VI) + (VII) + (IX)). Totally, there are 26 firms with significant exchange rate exposures. Therefore, the traditional symmetric measures of exchange rate exposures seem to underestimate exchange rate risks. The "exposure puzzle", to some extent, may be due to the estimating methods of exchange rate exposures.

In addition, sectors with asymmetric exposures concentrate in the cells of (III) and (VI), indicating that the source of asymmetry comes from certain firm behaviors, such as asymmetric hedge or PTM with VC[2].

Table 4. Asymmetric estimates over one-month horizon

	$\beta_2 > 0$	$\beta_2 = 0$	$\beta_2 < 0$	Row total
$\beta_3 > 0$	(I) 0 (0%)	(IV) 1 (0.709%)	(VII) 0 (0%)	1 (0.709%)
$\beta_3 = 0$	(II) 4 (2.837%)	(V) 115 (81.56%)	(VIII) 4 (2.837%)	123 (87.234%)
$\beta_3 < 0$	(III) 6 (4.255%)	(VI) 11 (7.801%)	(IX) 0 (0%)	17 (12.057%)
Column total	10 (7.092%)	127 (90.07%)	4 (2.837%)	141 (100%)

Note: This table provides results of the asymmetric model over one-month horizon:

$$R_{it} = \beta_0 + \beta_1 R_{mt} + \beta_2 R_{st} + \beta_3 D_{it} R_{st} + \varepsilon_{it,}$$

$$D_{it} = \begin{cases} 1 & if \quad R_{st} \le 0 \\ 0 & if \quad R_{st} > 0. \end{cases}$$

3.3. Discussion. Our empirical result that export-oriented Taiwanese firms are adversely affected by a weakening NT dollar and benefiting from a strengthening NT dollar is contradictory to conventional expectation. One possible interpretation is the so-called J-curve effect, a phenomenon caused by inelasticity in the short run.

Specifically, following domestic currency depreciation, the immediate effect is not a quantity adjustment (more exports and less imports), but a price adjustment. Because imports are more expensive

[1] The same table is shown in Koutmos and Martin (2003).

[2] Please refer to Table 3.

and exports are cheaper in terms of domestic currency, firm's earnings will decline in the short run. As the time horizon lengthens, the quantity of exports begins to rise, and the quantity of imports begins to decline. Thus, a firm's earning may actually worsen before it improves following domestic currency depreciation.

We want to examine whether our results vary with return horizons, and whether the J-curve effect exists in Taiwanese firms. Equations (1) and (2) are used again for longer return horizons: three-month, six-month, and twelve-month[1].

Table 5 presents the empirical results of equation (1) over different return horizons. The findings are as follows: First, the number of negative coefficients is 54(4), 72(8), 83(26), and 90(43), while the number of positive coefficients is 87(9), 69(8), 58(13), and 51(26) over one-month, three-month, six-month, and twelve-month horizons, respectively[2]. The number of negative coefficients is larger than the positive one over a one-month horizon, a result contradictory to our expectations, since Taiwan is an export-oriented economy. However, the number of positive coefficients becomes larger as the return horizons lengthen, and then exceeds the negative coefficients over three-month, six-month, and twelve-month horizons. Therefore, the situation that more firms are with negative exposures is only in the short run. In the long run, more firms are with positive exposures, and the result is consistent with our expectations. The J-curve effect indeed exists among Taiwanese firms.

Second, the "exposure puzzle" only occurs in the short run. As the return horizons lengthen, the number of significant exposures increases. Specifically, the number of firms with significant exposure is 13, 16, 39 and 69 over one-month, three-month, six-month, and twelve-month horizons, respectively. In the twelve-month horizon, near 50% firms are with significant exchange rate exposures. Our results are consistent with those of Chow, Lee, and Solt (1997a, b).

Table 5. Results of traditional symmetric models over different return horizons

	One-month		Three-month		Six-month		Twelve-month	
	β_2 >0	β_2 <0	β_2 >0	β_2 <0	β_2 >0	β_2 <0	β_2 >0	β_2 <0
No. of Coefficient	54	87	72	69	83	58	90	51
No. of Significance	4	9	8	8	26	13	43	26
Overall	13		16		39		69	
(percentage)	(9.21%)		(11.35%)		(27.66%)		(48.94%)	

Note: This table provides results of the traditional symmetric model over different return horizons: $R_{it} = \beta_0 + \beta_1 R_{mt} + \beta_2 R_{st} + \varepsilon_{it}$, where R_{it} is the stock return of firm i in period t; R_{mt} is the return of market portfolio in period t; R_{st} is the exchange rate change in period t; ε_{it} is the error term in period t; β_0, β_1, and β_2 are regression parameters.

Tables 6, 7, 8 present the empirical results from the asymmetric models over three-month, six-month, and twelve-month return horizons. The findings are as follows. First, the number of symmetric exposure (cells (II) + (VIII)) is 12, 24 and 34, while the number of asymmetric exposure (cells (I) + (III) + (IV) + (VI) + (VII) + (IX)) is 23, 31 and 61, respectively. In these return horizons, firms are also rarely exposed symmetrically to currency appreciations and depreciations. However, a larger percentage of them are exposed asymmetrically to currency appreciations and depreciations. Overall, our results provide evidence that firms have more significant exposures over longer return horizons in the asymmetric models. About 68% Taiwanese firms actively exploit opportunities and avoid adverse effects to exchange rate changes in the long run (twelve-month horizon) since they are exposed asymmetrically.

Second, sectors with asymmetric exposures concentrate in the cells of (IV) and (VII), indicating that the source of asymmetry comes from certain firm behaviors such as PTM with MOS[3].

Third, the number of net exporters (cells (I) + (II) + (III) + (VI)) is 11, 22, 35 and 60, while the number of net importers (cells (VI) + (VII) + (VIII) + (IX)) is 15, 13, 20 and 35 over one-month, three-month, six-month, and twelve-month horizons, respectively. There is also a J-curve effect since the number of net exporters is greater than that of net importers in longer horizons.

[1] Longer-horizon returns are continuously compounded over the corresponding interval, and the estimation is based on overlapping monthly observations, following the method of Bodnar and Wong (2003). The serious correlation induced by the use of overlapping observations is corrected using the method of Newey and West (1987). Moreover, we conduct all significance tests at the 5% level for each tail, with the degree of freedom equal to the number of non-overlapping observations (rather than the actual degree of freedom).

[2] The figure in the parentheses is the number with significant exposure.

[3] Please refer to Table 3.

We then summarize the results of firms with significant exchange rate exposure using the symmetric and asymmetric models in Table 9, respectively. The number of firms with significant exposure is 13, 16, 39 and 69 in the traditional symmetric model, while the number of firms with significant exposure is 26, 35, 55 and 95 in the asymmetric model. The number of firms with exchange rate exposure is larger when the asymmetric model is used no matter in the short or long run. Therefore, the traditional symmetric measures of exchange rate exposures may underestimate exchange rate risks.

Table 6. Asymmetric estimates over three-month horizon

	$\beta_2 > 0$	$\beta_2 = 0$	$\beta_2 < 0$	Row total
$\beta_3 > 0$	(I) 0 (0%)	(IV) 11 (7.801%)	(VII) 3 (2.128%)	14 (9.929%)
$\beta_3 = 0$	(II) 8 (5.674%)	(V) 106 (75.177%)	(VIII) 4 (2.837%)	118 (83.688%)
$\beta_3 < 0$	(III) 3 (2.128%)	(VI) 6 (4.255%)	(IX) 0 (0%)	9 (6.383%)
Column total	11 (7.801%)	123 (87.234 %)	7 (4.965 %)	141 (100%)

Note: This table provides results of the asymmetric model over three-month horizon:

$$R_{it} = \beta_0 + \beta_1 R_{mt} + \beta_2 R_{st} + \beta_3 D_{it} R_{st} + \varepsilon_{it},$$

$$D_{it} = \begin{cases} 1 & if \quad R_{st} \le 0 \\ 0 & if \quad R_{st} > 0. \end{cases}$$

Table 7. Asymmetric estimates over six-month horizon

	$\beta_2 > 0$	$\beta_2 = 0$	$\beta_2 < 0$	Row total
$\beta_3 > 0$	(I) 0 (0%)	(IV) 14 (9.929%)	(VII) 11 (7.801)	25 (17.73%)
$\beta_3 = 0$	(II) 17 (12.057%)	(V) 86 (60.993%)	(VIII) 7 (4.965%)	110 (78.014%)
$\beta_3 < 0$	(III) 4 (2.837%)	(VI) 2 (1.418%)	(IX) 0 (0%)	6 (4.255%)
Column total	21 (14.894 %)	102 (72.34 %)	18 (12.766 %)	141 (100%)

Note: This table provides results of the asymmetric model over six-month horizon:

$$R_{it} = \beta_0 + \beta_1 R_{mt} + \beta_2 R_{st} + \beta_3 D_{it} R_{st} + \varepsilon_{it},$$

$$D_{it} = \begin{cases} 1 & if \quad R_{st} \le 0 \\ 0 & if \quad R_{st} > 0. \end{cases}$$

Table 8. Asymmetric estimates over twelve-month horizon

	$\beta_2 > 0$	$\beta_2 = 0$	$\beta_2 < 0$	Row total
$B_3 > 0$	(I) 5 (3.546%)	(IV) 38 (26.95%)	(VII) 12 (8.511%)	55 (39.007%)
$\beta_3 = 0$	(II) 13 (9.22%)	(V) 46 (32.624%)	(VIII) 21 (14.894%)	80 (56.738%)
$\beta_3 < 0$	(III) 4 (2.837%)	(VI) 1 (0.709%)	(IX) 1 (0.709%)	6 (4.255%)
Column total	22 (15.603 %)	85 (60.284%)	34 (24.113 %)	141 (100%)

Note: This table provides results of the asymmetric model over twelve-month horizon:

$$R_{it} = \beta_0 + \beta_1 R_{mt} + \beta_2 R_{st} + \beta_3 D_{it} R_{st} + \varepsilon_{it},$$

$$D_{it} = \begin{cases} 1 & if \quad R_{st} \le 0 \\ 0 & if \quad R_{st} > 0. \end{cases}$$

Table 9. Number of firms with significant exchange rate exposures using traditional symmetric models and asymmetric models over different return horizons

	One-month		Three-month		Six-month		Twelve-month	
Traditional symmetric models	13		16		39		69	
Asymmetric models	Sym. 8	Asym. 18	Sym. 12	Asym. 23	Sym. 24	Asym. 31	Sym. 34	Asym. 61
	26		35		55		95	

Note: "Sym" refers to symmetric exposure; "Asym" refers to asymmetric exposure.

Conclusion

Taiwan is a small open economy. One may expect firms in a more open economy to be more sensitive to movements in the exchange rate. In the traditional symmetric model, our results show the lack support of this view. In the asymmetric model, Taiwanese firms' exposures to foreign exchange rate movements are rarely symmetric for currency appreciations and depreciations. However, there is considerable asymmetric exchange rate exposure. Therefore, the "exposure puzzle", to some extent, may be due to the estimating methods of exchange rate exposures. The traditional symmetric measures of exchange rate exposures may underestimate exchange rate risks. In addition, this underestimation is associated with wrong direction in the long run due to the J-curve effect of Taiwanese firms. Only when considering potential asymmetric exposure components can firms' financial exposures be estimated and hedged properly.

Further research can use other country's data to investigate the asymmetric exchange rate exposures of firms in the short and long run, and compare the results with those of the traditional symmetric model.

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