Asymmetric Currency Exposure: Evidence from Taiwan Industries

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Most of previous studies have not been successful in finding significant currency exposure. One possible explanation for this failure is that these studies ignore the asymmetric relationship between the value of a firm and exchange rate. Consequently, in this paper I explore the possibility of asymmetric currency exposure using industry returns from an export-oriented country - Taiwan. The empirical results show that all industries respond the movements of bilateral USD/NTD exchange rate asymmetrically based on the tests of a multi-factor model with multivariate GARCH parameterization. The asymmetric exposures are not only statistically but also economically significant. In addition, this empirical finding is robust to whether contemporaneous or lagged currency changes are used to estimate the exposures. The strong evidence of asymmetric currency exposure points out the advantage of MGARCH approach over the traditional OLS/SUR approaches.

INTRODUCTION

According to Adler and Dumas (1980, 1984), currency (or exchange rate) exposure can be obtained by regressing changes in firm value against exchange rate changes. However, previous empirical studies have very limited success in detecting it (e.g., Jorion (1990), Bodnar and Gentry (1993), Bartov and Bodnar (1994), Chow et al. (1997), He and Ng (1998), Allayannis and Ofek (2001), Griffin and Stulz (2001), among others). Jorion (1990), the first major study on this issue, finds that only 5.2% of 287 US multinationals show a significant exposure. Subsequent studies by Bodnar and Gentry (1993), Bartov and Bodnar (1994) find similar results. Using Japanese data, He and Ng (1998) find that only 25% of the 171 multinationals in their sample have significant exposure. Griffin and Stulz (2001) use industry returns from developed markets and fail to find evidence of exposure. Several potential explanations exist for these weak results. One of the explanations pointed out by Bartov and Bodnar (1994) is that existing studies investigate almost exclusively linear/symmetric currency exposure and may fail to account for possible nonlinear/asymmetric relationship between the value of a firm and exchange rate, which motivates the current paper. In addition, theoretical literature suggests that firm behavior may well be different in periods of depreciation and appreciation, which should have an impact on how exchange rates affect the firm value. For example, the asymmetric responses of stock prices to currency movements can be attributed to firms' pricing-to-market behavior (Froot and Klemperer (1989), Knetter (1989, 1994), and Marston (1990)), hysteretic behavior (Baldwin (1988), Baldwin and Krugman (1989), and Dixit (1989)), and asymmetric hedging behavior.[1] Although theoretically sounded, this asymmetric response of stock returns to currency appreciations and depreciations has received very little attention in the literature.[2] Consequently, the current paper attempts to fill this gap by testing asymmetric currency exposure.

In this paper I examine asymmetric currency exposure using industry returns from an export-oriented country- Taiwan, Republic of China (ROC). The current paper extends the existing literature in several important ways that provides new insights about the nature of currency exposure. First, I go beyond the traditional regression framework that imposes a linear relation between exchange rates and stock returns and allow for potentially different impacts of exchange rates during periods of depreciating versus appreciating currency values. That is, I investigate the possibility of asymmetric currency exposure that has not been fully explored in the literature. Second, I apply multivariate GARCH (MGARCH) methodology to estimate asymmetric currency exposure coefficients. Most studies dealing with currency exposure use OLS or seeming unrelated regression (SUR) (e.g., Jorion (1991), Choi et al. (1992), Bodnar and Gentry (1993), Chow et al. (1997), among others). Without taking into account second moment temporal dependencies in asset returns, which have been documented extensively in literature (see, e.g., Hsieh (1989), Bollerslev et al. (1992), among others), both OLS and SUR will produce inefficient parameter estimates as well as biased test statistics, which may explain why previous studies have had difficulty finding significant currency exposure. The multivariate approach employed in this paper allows me to utilize the information in the entire variance-covariance matrix of the errors, which, in turn, leads to more precise estimates of the parameters of the model.[3] Finally, to ensure robust results, both contemporaneous and lagged exchange rate changes are used since Bartov and Bodnar (1994) show that lagged exchange rate changes are significantly related to stock returns for a subset of US firms.

The empirical results show strong evidence of asymmetric currency exposures with respect to bilateral exchange rate between US dollar and New Taiwan dollar based on the tests of multi-factor model with MGARCH parameterization. The asymmetric exposures are not only statistically but also economically significant. This empirical finding is robust to whether contemporaneous or lagged exchange rates changes are used to estimate the exposures.

The remainder of the paper is organized as follows. Section 2 presents asymmetric multi-factor model. Section 3 describes the econometric methodologies used to test the model. Section 4 discusses the data. Section 5 reports and discusses the empirical results. Concluding comments are offered in Section 6.

THE ASYMMETRIC MULTI-FACTOR MODEL

Following the existing literature, a multi-factor model similar to that of Choi et al. (1992) is used to describe the returns on Taiwan industries. The model is:

$$r_{i,t} = \beta_{im} r_{m,t} + \beta_{i\,\text{int}} r_{\text{int},t} + \beta_{ic} r_{c,t} + \varepsilon_{i.t} \tag{1}$$

where r_{it} is excess return on individual industry i; $r_{m,t}$ is excess return on a world market index ; $r_{\text{int},t}$ is return on an interest rate factor; $r_{c,t}$ is return on a currency factor; β_{im}, $\beta_{i\,\text{int}}$, and β_{ic} are exposure coefficients with respect to world market, interest rate, and currency movements, respectively, and ε_{it} is unexpected return or innovation of industry i. To incorporate the asymmetric currency exposure in the model, equation (1) can be modified as:

$$r_{i,t} = \beta_{im} r_{m,t} + \beta_{i\,\text{int}} r_{\text{int},t} + (\beta_{ic} + \beta_{ic}^{d} D_t) r_{c,t} + \varepsilon_{i.t} \tag{2}$$

where D_t is a dummy variable, which is equal to one if $r_{c,t} < 0$ and zero otherwise. For given values of market index and interest rate factor, the response of $r_{i,t}$ will be equal to β_{ic} when $r_{c,t} > 0$ and $\beta_{ic} + \beta_{ic}^{d}$ for $r_{c,t} < 0$. Equation (2) can be used to test the null hypothesis that currency exposure is symmetric, i.e., $H_0 : \beta_{ic}^d = 0$. The total impact of currency movements on industry returns can be measured by the sum of β_{ic} and β_{ic}^d coefficients.

ECONOMETRIC METHODOLOGY

The asymmetric three-factor model in equation (2) has to hold for every asset. However, the model does not impose any restrictions on the dynamics of the conditional second moments. Given the computational difficulties in estimating a larger system of asset returns, parsimony becomes an important factor in choosing different parameterizations. A popular parameterization of the dynamics of the conditional second moments is BEKK, proposed by Baba, Engle, Kraft, and Kroner (1989). The major feature of this parameterization is that it guarantees that the variance-covariance matrices in the system are positive definite. However, it still requires researchers to estimate a larger number of parameters. Instead of using BEKK specification, I employ a parsimonious parameterization of the conditional variance-covariance structure of asset returns and risk factors proposed by Ding and Engle (1994). Their parameterization allows me to reduce the number of parameters to be estimated significantly.[4]

Under Ding and Engle's parameterization, the conditional second moments is assumed to follow a diagonal process and the system is assumed to be covariance stationary; therefore, the GARCH process for the conditional variance-covariance matrix of asset returns and risk factors can be written as,

$$\mathbf{H}_{\mathrm{t}} = \mathbf{H}_0 * (\boldsymbol{\iota\iota}^{\mathrm{T}} - \mathbf{aa}^{\mathrm{T}} - \mathbf{bb}^{\mathrm{T}}) + \mathbf{aa}^{\mathrm{T}} * \boldsymbol{\varepsilon}_{\mathrm{t-1}}\boldsymbol{\varepsilon}_{\mathrm{t-1}}^{\mathrm{T}} + \mathbf{bb}^{\mathrm{T}} * \mathbf{H}_{\mathrm{t-1}} \tag{3}$$

where $\mathbf{H}_{\mathrm{t}} \in \mathbf{R}^{\mathrm{N\times N}}$ is a time-varying variance-covariance matrix of bank stock returns. $\mathbf{H}_0$ is the unconditional variance-covariance matrix of innovations. $\boldsymbol{\iota}$ is a $\mathrm{N} \times 1$ vector of ones, $\mathbf{a},\mathbf{b} \in \mathbf{R}^{\mathrm{N\times 1}}$ are vectors of unknown parameters, and * denotes element-by-element matrix product. The $\mathbf{H}_0$ is unobservable and has to be estimated. As suggested by De Santis and Gerard (1997, 1998), it can be consistently estimated using iterative procedure. In particular, $\mathbf{H}_0$ is set equal to the sample covariance matrix of the asset returns in the first iteration, and then it is updated using the covariance matrix of the estimated residual at the end of each iteration.

Under the assumption of conditional normality, the log-likelihood to be maximized under both processes can be written as,

$$\ln L(\boldsymbol{\theta}) = -\frac{\mathrm{T} \times (\mathrm{N}+\mathrm{K})}{2} \ln 2\pi - \frac{1}{2}\sum_{\mathrm{t=1}}^{\mathrm{T}} \ln|\mathbf{H}_t(\boldsymbol{\theta})| - \frac{1}{2}\sum_{\mathrm{t=1}}^{\mathrm{T}} \boldsymbol{\varepsilon}_t(\boldsymbol{\theta})^{\mathrm{T}}\ \mathbf{H}_{\mathrm{t}}(\boldsymbol{\theta})^{-1}\boldsymbol{\varepsilon}_{\mathrm{t}}(\boldsymbol{\theta}) \tag{4}$$

where $\boldsymbol{\theta}$ is the vector of unknown parameters in the model. Since the normality assumption is often violated in financial time series, the quasi-maximum likelihood estimation (QML) proposed by Bollerslev and Wooldridge (1992) which allows inference in the presence of departures from conditional normality is employed. Under standard regularity conditions, the QML estimator is consistent and asymptotically normal and statistical inferences can be carried out by computing robust Wald statistics. The QML estimates can be obtained by maximizing equation (4), and calculating a robust estimate of the covariance of the parameter estimates using the matrix of second derivatives and the average of the period-by-period outer products of the gradient. Optimization is performed using the Broyden, Fletcher, Goldfarb and Shanno (BFGS) algorithm, and the robust variance-covariance matrix of the estimated parameters is computed from the last BFGS iteration.

DATA AND SUMMARY STATISTICS

Given the computational difficulties in estimating a larger system of asset returns, ten major Taiwan industries with weekly data over the sample period 01/05/90 – 03/15/13 (1211 observations) are selected to test asymmetric currency exposure. These ten industries are Automobiles (AUTOS), Consumer Goods (CNSMG), Food Products (FDPRD), Electronic Equipment (ELTNC), Semiconductors (SEMIC), Banks (BANKS), Consumer Services (CNSMS), Financial Services (FINSV), Industrial Transport (INDTR), and Industrials (INDUS). The excess industry return is calculated as the log first difference of industry total return index (including dividends) in excess of a 7-day Eurodollar deposit rate. Three risk factors are a world market risk measured as the log first difference of Datastream world total return index in excess of the 7-day Eurodollar deposit rate (TOTMK), an interest rate risk measured as the change of a 10-year Treasury constant maturity rate in excess of the 7-day Eurodollar deposit rate (USTP), and a currency risk measured as the log first difference of US dollar and New Taiwan dollar bilateral exchange rate (USD/NTD). The exchange rate is expressed as US dollar price per unit of New Taiwan dollar, so a positive change indicates a decreasing value of the USD. All the data are extracted from Datastream.

TABLE 1 presents descriptive statistics of the continuously compounded weekly returns on industry returns and risk factors. As can be seen from Panel A, the Semiconductors (SEMIC) records the highest mean of 0.122% per week, while Financial Services (FINSV) records the lowest mean of -0.148% per week. For USD/NTD bilateral exchange rate, it has a negative mean of -0.011%, indicating that the USD was appreciating on average against New Taiwan Dollar during the sample period. For interest rate factor, its mean return is 0.078%, and for world market index, its mean return is 0.064%. In addition to mean returns, Panel A also reports pairwise correlation coefficients between industry returns and each one of the risk factors. Almost all the industries are negatively correlated with exchange rate, indicating that these

TABLE 1
DESCRIPTIVE STATISTICS

	Mean	Std	Min	Max	$\rho_{i,NTD}$	$\rho_{i,\text{int}}$	$\rho_{i,mkt}$	Kurtosis
Panel A: Industry Returns								
AUTOS	-0.012	5.952	-27.900	28.421	-0.015	0.056	-0.029	2.493**
CNSMG	0.021	4.690	-24.798	24.779	-0.009	0.037	-0.021	3.038**
FDPRD	0.079	5.306	-57.557	23.707	-0.025	0.004	-0.006	13.689**
ELTNC	0.034	5.298	-26.225	38.436	-0.002	0.039	-0.017	4.162**
SEMIC	0.122	5.903	-28.143	27.869	0.020	0.039	-0.010	2.758**
BANKS	-0.103	5.304	-25.870	27.202	0.039	0.040	-0.013	3.668**
CNSMS	-0.087	4.881	-24.187	25.494	-0.017	-0.015	-0.062	3.672**
FINSV	-0.148	5.524	-31.911	35.666	0.014	0.017	-0.024	5.053**
INDTR	-0.065	6.105	-27.654	25.494	-0.003	0.020	-0.050	2.123**
INDUS	0.025	5.240	-26.413	36.317	-0.001	0.054	-0.036	3.837**
Panel B: Risk Factors								
USD/NTD	1							
USTP	0.065	1						
TOTMK	0.288	0.134	1					

Panel A presents descriptive statistics for the weekly dollar-denominated excess Taiwan industry returns and the pairwise correlation coefficients between each industry return and one of the three risk factors from 01/19/90 through 03/15/13 (1209 observations). Panel B shows the same statistics and the pairwise correlation coefficients for the risk factors. $\rho_{i,NTD}$ is the correlation coefficients between industry return i and USD/NTD movements, $\rho_{i,\text{int}}$ is the correlation coefficient between each industry return i and interest rate risk and $\rho_{i,mkt}$ is the correlation coefficient between each industry return i and world market risk. ** denotes statistically significant at the 1% level.

industries benefit from a weak New Taiwan dollar. The distribution of the industry returns in all instances show significant excess kurtosis, suggesting that the return series are conditionally heteroskedastic (see Bollerslev et al. (1992)). The use of GARCH model will be able to take this into account.

EMPIRICAL RESULTS

Main Empirical Result Using Bilateral Rate

TABLE 2 reports the estimation results for the asymmetric three-factor model (equation (2)). First consider the market risk exposure coefficients β_m, as can be seen in TABLE 2, they are all significantly positive at the 1% level, suggesting that Taiwan industries benefit from a bull world stock market. In terms of the size of β_m, it ranges from 0.347 (INDUS) to 0.177 (CNSMS), with an average of 0.273. On the contrary, the interest rate exposure coefficients β_{int} varying from 0.013 (AUTOS) to –0.040 (FDPRD) with a mean of –0.007 are not significant, indicating that Taiwan industries are not exposed to the change in the US term premium. Now considering the bilateral currency exposure, all industries are significantly negatively exposed to USD/NTD movements as can be seen from TABLE 2, and 90% (9 out of 10) of the significant currency exposures are asymmetric during currency appreciations and depreciations. The overall impact of USD/NTD movements on industry returns can be assessed by adding the estimated β_{NTD} to β_{NTD}^d coefficients, and $\beta_{NTD} + \beta_{NTD}^d$ are negative in all cases. One of the theoretical explanations about asymmetric currency exposure is asymmetric hedging behavior. Asymmetric hedging occurs when firms take one-sided hedges, such as with the use of currency options. Firms with net long positions in foreign currencies (or net short positions in domestic currencies) may be willing to hedge against domestic currency appreciations yet remain unhedged against domestic currency depreciations. As a result, we would observe a positive exposure (no exposure) when foreign currency appreciates (depreciates). On the other hand, firms with net short positions in foreign currencies (or net long positions in domestic currencies) are likely to hedge against domestic currency depreciations (no exposure) but remain unhedged against domestic currency appreciations (negative exposure). Thus, asymmetric hedging behavior produces an asymmetric impact on firms' cash flows. Since β_{NTD}^d is significantly positive for all industries, it suggests that Taiwan industries benefit when NTD depreciates against the USD. In terms of the size of $\beta_{NTD} + \beta_{NTD}^d$, it ranges from -1.317 for AUTOS to -0.831 for BANKS, with an average of -1.165, indicating ceteris paribus a 1% appreciation of the USD with respect NTD is, on average, associated with a 1.165% increase in Taiwan industry returns. As a result, the currency exposures are not only statistically but also economically significant. This is an extremely important finding as it suggests that models assuming symmetric exposure over appreciation-depreciation cycles are frequently misspecified. Previous studies failing to detect significant currency exposure often suggest that firms largely hedge their currency exposure.[5] However, the findings presented here imply that complete hedging is less likely for Taiwan industries.

Next, consider the estimated parameters for the conditional variance-covariance processes. All of the elements in the vectors $\mathbf{a}$ and $\mathbf{b}$ are statistically significant at the 1% level, implying that strong GARCH effect is present for all the return series. In addition, the estimates satisfy stationarity conditions for all the variance and covariance processes.[6] The presence of conditional heteroskedasticity and the high degree of volatility persistence suggest that using simple OLS or SUR, which assume constant variance, will lead to high standard errors and erroneous inferences.[7] This may provide another reason why previous studies have failed to detect significant currency exposure.

TABLE 2
CONDITIONAL THREE-FACTOR MODEL: USD/NTD

	Conditional Mean Process								***Conditional Variance Process***			
	β_m		β_{int}		β_{NTD}		β^d_{NTD}		a		b	
AUTOS	0.313	(0.065**)	0.013	(0.032)	-1.884	(0.313**)	1.373	(0.568*)	0.205	(0.005**)	0.976	(0.002**)
CNSMG	0.305	(0.058**)	-0.005	(0.026)	-1.531	(0.283**)	1.070	(0.471*)	0.203	(0.005**)	0.975	(0.002**)
FDPRD	0.284	(0.063**)	-0.040	(0.025)	-1.601	(0.364**)	0.792	(0.488)	0.208	(0.009**)	0.974	(0.003**)
ELTNC	0.347	(0.070**)	0.009	(0.031)	-2.087	(0.324**)	1.715	(0.624**)	0.225	(0.004**)	0.974	(0.001**)
SEMIC	0.264	(0.065**)	0.007	(0.025)	-1.760	(0.292**)	1.470	(0.507**)	0.218	(0.005**)	0.974	(0.002**)
BANKS	0.221	(0.063**)	0.005	(0.026)	-1.281	(0.300**)	1.330	(0.450**)	0.176	(0.007**)	0.979	(0.002**)
CNSMS	0.177	(0.057**)	-0.019	(0.023)	-1.432	(0.270**)	1.205	(0.421**)	0.199	(0.008**)	0.975	(0.003**)
FINSV	0.277	(0.071**)	-0.026	(0.031)	-1.621	(0.300**)	1.452	(0.473**)	0.189	(0.007**)	0.977	(0.002**)
INDTR	0.192	(0.068**)	-0.017	(0.026)	-1.529	(0.352**)	1.376	(0.534**)	0.199	(0.009**)	0.976	(0.003**)
INDUS	0.347	(0.069**)	0.008	(0.031)	-2.082	(0.321**)	1.708	(0.621**)	0.225	(0.004**)	0.974	(0.001**)

Estimations are based on weekly dollar-denominated excess Taiwan industry returns from 01/19/90 through 03/15/13. Each mean equation relates the excess return $r_{i,t}$ to the world market ($r_{m,t}$), interest rate ($r_{\text{int},t}$), and USD/NTD currency risks ($r_{NTD,t}$).

$$r_{i,t} = \beta_{im} r_{m,t} + \beta_{i\,\text{int}} r_{\text{int},t} + (\beta_{iNTD} + \beta^d_{iNTD} D_t) r_{NTD,t} + \varepsilon_{i.t} \quad \forall i$$

where D_t is a dummy variable, which is equal to one if $r_{NTD,t} < 0$ and zero otherwise.

$$\boldsymbol{\varepsilon}_t \mid \Omega_{t-1} \sim N(0, \mathbf{H}_t)$$

The conditional covariance matrix $\mathbf{H}_t$ is parameterized as follows

$$\mathbf{H}_t = \mathbf{H}_0 * (\boldsymbol{\iota\iota}^T - \mathbf{aa}^T - \mathbf{bb}^T) + \mathbf{aa}^T * \boldsymbol{\varepsilon}_{t-1}\boldsymbol{\varepsilon}_{t-1}^T + \mathbf{bb}^T * \mathbf{H}_{t-1}$$

where $\mathbf{H}_t \in \mathbf{R}^{10\times10}$ is the conditional covariance matrix of Taiwan industry returns. The elements of vectors $\mathbf{a,b} \in \mathbf{R}^{10\times1}$ are the GARCH parameters, $\boldsymbol{\iota}$ is a 10 x 1 unit vector and ***** denotes the Hadamard product (element-by-element multiplication). QML standard errors are reported in parentheses. * and ** denote statistical significance at the 5% and 1% level, respectively.

Exposure to a Lagged Bilateral Rate

Bartov and Bodnar (1994) argue that the failure of finding significant currency exposure is due to mispricing because they find lagged changes in the USD are a significant variable in explaining stock returns. This mispricing according to them arises from systematic errors by investors in the estimation of the relation between movements in USD and firm value and implies that stock price adjustments due to movements in the USD take time as opposed to occurring instantaneously, which suggests a violation of efficient market hypothesis. Earlier studies in testing this mispricing argument find mixed results. For example, Amihud (1994) finds little evidence of a relation between lagged changes in USD on stock returns for a sample of the 32 largest US exporters from 1982 to 1988. Using 208 sample firms from 36 different industries over the 1978-1990 time period, Bartov and Bodnar (1994) fail to find a significant relation between contemporaneous changes of the trade-weighted value of the USD and the stock performance of their sample firms, but detect a significant relation when the lagged changes in the trade-weighted value of the USD is used. To address this issue, I re-estimate the asymmetric multi-factor model by using lagged changes in bilateral USD/USD rate. The estimation results about asymmetric currency exposure reported in TABLE 3 are similar to those reported in TABLE 2. That is, all industries respond significantly to lagged USD/NTD movements. In particular, β_{NTD}, ranging from -2.355 (ELTNC) to -1.578 (SEMIC) with an average of -1.958, are significantly negative, indicating that overall Taiwan industries suffer from a strong home currency. As for the asymmetric currency exposure, β^d_{NTD}, ranging from 3.309 (ELTNC) to 2.025 (FDPRD) with an average of 2.650, are all significantly positive, indicating that Taiwan industries benefit from a weak home currency, which is not surprising since Taiwan is an export-oriented country. Consequently, the mispricing argument may not be responsible for the failure of detecting significant contemporaneous relation between currency changes and stock returns, and one possible reason for this failure may be the ignorance of both asymmetric currency exposure and conditional heteroskedasticity in the error terms combined with the possibility of cross-asset dependencies mentioned earlier.

Using nine US sector indices with respect to 5 different bilateral exchange rates over the 1992-1998 time period, a study by Koutmos and Martin (2003b) show that none of their sample is exposed to either the contemporaneous or lagged changes in USD/JPY rate, a result which is in sharp contrast to the strong results found here. One possible reason may explain this difference is that they use a univariate GARCH instead of the multivariate GARCH approach to estimate each sector index separately, and consequently cross-asset dependencies are ignored.

TABLE 3
CONDITIONAL THREE-FACTOR MODEL: LAGGED USD/NTD

	Conditional Mean Process								***Conditional Variance Process***			
	β_m		β_{int}		β_{NTD}		β^d_{NTD}		a		b	
AUTOS	-0.122	(0.053*)	-0.038	(0.039)	-2.191	(0.321**)	3.088	(0.482**)	0.218	(0.006**)	0.972	(0.002**)
CNSMG	-0.066	(0.044)	-0.043	(0.031)	-1.930	(0.274**)	2.508	(0.416**)	0.216	(0.004**)	0.972	(0.001**)
FDPRD	-0.083	(0.046)	-0.068	(0.028*)	-1.680	(0.280**)	2.025	(0.387**)	0.218	(0.011**)	0.970	(0.004**)
ELTNC	-0.113	(0.049*)	-0.037	(0.040)	-2.355	(0.306**)	3.309	(0.479**)	0.245	(0.004**)	0.969	(0.001**)
SEMIC	-0.115	(0.048*)	-0.025	(0.031)	-1.578	(0.294**)	2.617	(0.451**)	0.235	(0.007**)	0.969	(0.002**)
BANKS	-0.101	(0.047*)	-0.030	(0.029)	-1.667	(0.291**)	2.252	(0.417**)	0.188	(0.008**)	0.976	(0.003**)
CNSMS	-0.133	(0.047**)	-0.052	(0.026*)	-1.839	(0.257**)	2.284	(0.381**)	0.206	(0.007**)	0.973	(0.002**)
FINSV	-0.103	(0.050*)	-0.063	(0.034)	-2.044	(0.281**)	2.604	(0.430**)	0.203	(0.008**)	0.973	(0.003**)
INDTR	-0.154	(0.060*)	-0.056	(0.031)	-1.947	(0.293**)	2.508	(0.400**)	0.206	(0.008**)	0.974	(0.003**)
INDUS	-0.112	(0.048*)	-0.039	(0.040)	-2.350	(0.305**)	3.307	(0.476**)	0.244	(0.004**)	0.969	(0.001**)

Estimations are based on weekly dollar-denominated excess Taiwan industry returns from 01/19/90 through 03/15/13. Each mean equation relates the excess return $r_{i,t}$ to the world market ($r_{m,t}$), interest rate ($r_{\text{int},t}$), and lagged USD/NTD currency risks ($r_{NTD,t-1}$).

$$r_{i,t} = \beta_{im} r_{m,t} + \beta_{i\,\text{int}} r_{\text{int},t} + (\beta_{iNTD} + \beta^d_{iNTD} D_t) r_{NTD,t-1} + \varepsilon_{i.t} \quad \forall i$$

where D_t is a dummy variable, which is equal to one if $r_{NTD,t} < 0$ and zero otherwise.

$$\boldsymbol{\varepsilon}_t \mid \Omega_{t-1} \sim N(0, \mathbf{H}_t)$$

The conditional covariance matrix $\mathbf{H}_t$ is parameterized as follows

$$\mathbf{H}_t = \mathbf{H}_0 * (\boldsymbol{\iota\iota}^{\mathrm{T}} - \mathbf{aa}^{\mathrm{T}} - \mathbf{bb}^{\mathrm{T}}) + \mathbf{aa}^{\mathrm{T}} * \boldsymbol{\varepsilon}_{t-1}\boldsymbol{\varepsilon}^{\mathrm{T}}_{t-1} + \mathbf{bb}^{\mathrm{T}} * \mathbf{H}_{t-1}$$

where $\mathbf{H}_t \in \mathbf{R}^{10\times 10}$ is the conditional covariance matrix of Taiwan industry returns. The elements of vectors $\mathbf{a},\mathbf{b} \in \mathbf{R}^{10\times 1}$ are the GARCH parameters, $\boldsymbol{\iota}$ is a 10 x 1 unit vector and ***** denotes the Hadamard product (element-by-element multiplication). QML standard errors are reported in parentheses. * and ** denote statistical significance at the 5% and 1% level, respectively.

CONCLUSION

Most of previous studies have not been successful in detecting significant currency exposure. One possible explanation for this failure is that these studies ignore the asymmetric relationship between the value of a firm and exchange rate. As a result, in this paper I explore the possibility of asymmetric currency exposure that may explain why prior studies, which focus exclusively on linear/symmetric exposure, have difficulty in detecting it. Using industry returns from an export-oriented country - Taiwan, I find that all industries respond the movements of bilateral USD/NTD exchange rate asymmetrically based on the tests of a multi-factor model with multivariate GARCH parameterization. The asymmetric currency exposures are not only statistically but also economically significant. In addition, this empirical finding is robust to whether contemporaneous or lagged currency changes are used to estimate the exposures. The strong evidence of asymmetric currency exposure points out the advantage of MGARCH approach over the traditional OLS/SUR approaches.

ENDNOTES

1. Hysteretic behavior refers to a situation where new export competitors are enticed to enter the market when the domestic currency depreciates, but their behavior is considered hysteretic if they still remain in the market once the currency appreciates. Baldwin (1988) argues that the existence of such entry costs may lead to hysteresis when there are large swings in the dollar. If the swing in the dollar is of sufficient size this would induce foreign firms to enter the market place. However, because entry costs are sunk not all foreign firms leave the market when the exchange rate returns to its previous level. Consequently, this type of hysteretic behavior creates an asymmetric competitive effect, thus asymmetric exposure.
2. Two papers by Koutmos and Martin (2003a,b) have attempted to model asymmetric currency exposure using sector indices. Koutmos and Martin (2003a) find (in their Table 5) only 11.11% (7 out of 63) of their total weekly sample with significant asymmetric exposure. If considering the US data only, this percentage drops to 8.33% (3 out of 36). Using the same data set but at daily frequency, Koutmos and Martin (2003b) repeat the same exercise by adding conditional volatility of exchange rate changes in their model. The evidence of contemporaneous asymmetric exposure still remains very weak since only 4% (2 out of 45) of their US sample are asymmetrically exposed to currency risk. As a result, it demands another look at the asymmetric currency exposure.
3. Instead of estimating risk exposure coefficients *jointly*, Koutmos and Martin (2003a,b) apply univariate GARCH to estimate asymmetric currency exposure coefficient for each sector index separately, and thus ignore the possible cross-asset dependencies. Consequently, efficiency may be lost during the estimation, and which may explain why only limited evidence of asymmetric exposure is found in their studies using US sector indices.
4. In a diagonal system with N assets, the number of unknown parameters in the conditional variance equation is reduced from $2\mathrm{N}^2 + \frac{\mathrm{N}(\mathrm{N}+1)}{2}$ under BEKK specification to $2\mathrm{N}$ under Ding and Engle's specification.
5. Allayannis and Weston (2001) and Allayannis and Ofek (2001) document the use of currency derivatives for hedging exposure.
6. For the process in $\mathbf{H}_t$ to be covariance stationary, the condition $a_i a_j + b_i b_j < 1 \ \forall i, j$ has to be satisfied. (see, e.g., Bollerslev (1986), and De Santis and Gerard (1997, 1998))
7. The degree of volatility persistence can be obtained by comparing the parameter estimates a and b in the GARCH process. Since all the b estimates are in the range of 0.97 to 0.99, the volatility is highly persistence.

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