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ASYMMETRIC EXCHANGE RATE EXPOSURE AND INDUSTRY CHARACTERISTICS: EVIDENCE FROM JAPANESE DATA*

Chih-Chiang Hsu

Department of Economics, National Central University
Jhongli 320, Taiwan
cchsu@mgt.ncu.edu.tw

Ruey Yau

Department of Economics, National Central University
Jhongli 320, Taiwan
ryau@mgt.ncu.edu.tw

Jyun-Yi Wu**

Department of Economics, National Central University
Jhongli 320, Taiwan
jywu@mgt.ncu.edu.tw

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Abstract

This paper investigates the asymmetric effects of exchange rate exposure on Japanese stock returns at the industry level. Using the asymmetric correlation test of Hong et al. (2007), we examine five major currencies against the yen and thirty-three Japanese sectoral stock returns. Significant asymmetric responses in stock returns to exchange rate changes are found in the pharmaceutical, real estate, and air transportation industries. These findings are consistent with the pricing-to-market and hysteretic behavior for the pharmaceutical and air transportation industries and with the hedging behavior for the real estate industry. The results for the threshold models confirm that the asymmetric exposures are based on industry characteristics.

Keywords: exchange rate exposure, asymmetric correlation, threshold model
JEL Classification: F3, G15

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** Corresponding Author.

I. *Introduction*

Exchange rate exposure that measures the sensitivity of stock returns to exchange rate changes is an essential issue in financial management, because unexpected exchange rate changes may affect a firm's pricing decisions, future cash flows, and valuation. Shaprio (1975) proposes a two-country model to emphasize that a depreciation in the value of the home currency leads to an increase in the value of the home country firm and a decrease in the value of its foreign competitors. Given the theoretical prediction, empirical studies on the extent of exchange rate exposure, however, had limited success in terms of the extent of exposure implied by the theory. For instance, Jorion (1990), Amihud (1994), and Choi and Prasad (1995) find little evidence of significant exchange rate exposure based on samples of U.S. firms. In addition, Bondar and Gentry (1993) and Griffin and Stulz (2001) find a weak relationship between stock returns and exchange rate exposure at the industry level across countries.

In contrast with U.S. data, a number of studies provide strong evidence to support significant exchange rate exposure for Japanese firms. For example, He and Ng (1998) demonstrate that nearly 25% of the 171 Japanese multinationals exhibit significant exchange rate exposure. Chow and Chen (1998) show that Japanese firms are overwhelmingly negatively exposed, i.e., their equity returns decrease as the yen depreciates. On the contrary, Dominguez (1998) finds that yen depreciations are generally positively correlated with firm returns. By using a sample of automotive firms from the U.S. and Japan, Williamson (2001) finds that there exists exchange rate exposure across countries for multinational firms and their global competitors.

One possible explanation for these different empirical results is the existence of model misspecifications in the estimation of the sensitivity of stock returns to exchange rate changes; see Bartov and Bodnar (1994). Such a possibility has been explored in recent years by studies that analyze asymmetric responses of stock prices to currency movements. Miller and Reuer (1998) find that a small percentage of U.S. manufacturing firms exhibit asymmetric exposures. Muller and Verschoor (2006a) show that U.S. stock returns react asymmetrically to currency movements for 935 U.S. multinational firms. Using nine sector index returns, Koutmas and Martin (2003) provide evidence that asymmetries are found to be significant in the financial and non-cyclical sectors. Based on detailed industry classifications, it is still interesting to investigate the relationship between asymmetric exposure to exchange rates and industrial characteristics.

The first objective of this paper is to employ the asymmetric correlation test proposed by Hong et al. (2007) as a pretest for the existence of asymmetric exchange rate exposures in Japanese industrial data. If exchange rate exposure occurs only in one direction, using a sample that includes both directions could fail to detect a significant linear relationship that appears only in one direction. If the test results reject the null hypothesis of symmetry, then modeling the sensitivity of stock returns to exchange rate changes in a linear model is not appropriate. In this paper, a sample of 33 industrial stock returns listed on the Tokyo Stock Exchange is studied for exchange rate exposure. Of the thirty-three sectors under study, we find that three industries exhibit a significant asymmetric relationship between exchange rates and stock returns. The three industries are the pharmaceutical, real estate, and air transportation industries. This result provides evidence of a weak evidence relationship for the extent of currency risk exposure that the theoretical research predicts.

The second objective of this paper is to examine the type of firm behavior that is consistent with the observed asymmetric exchange rate exposure in these three industries. In theory, there are three types of behavior, namely, asymmetric hedging, hysteresis, and pricing-to-market, that give rise to different responses to positive versus negative news from exchange rate markets. These interpretations are associated with cost structures or the financial position of firms. Given the asymmetric correlation between the exchange rate movements and stock returns identified, it is not appropriate to use the linear statistical model. Instead, endogenous threshold models with GARCH errors proposed by Hansen (2000) are employed. The corresponding results further confirm the asymmetric effect. In addition, the asymmetry is consistent with the pricing-to-market and hysteresis behaviors for the pharmaceutical and air transportation sectors and with the hedging behavior for the real estate sector. We therefore conclude that the asymmetric exposure evidence is industry characteristic-specific.

The remainder of this study proceeds as below. Section 2 reviews the literature on asymmetric exchange rate exposures. Section 3 describes the test of Hong et al. (2007) that is used to examine asymmetric correlations. Section 4 reports the empirical results. Section 5 concludes.

II. *Asymmetric Responses to Exchange Rate Changes*

Jorion (1990) refers to exchange rate exposure as the sensitivity of a firm's value to exchange rate randomness. Earlier studies assume that the sensitivity of stock returns is symmetric to currency appreciation and depreciation. Since firms desire to gain more and lose less, this asymmetric attitude often causes them to respond to exchange rate swings. In the literature, asymmetric responses to exchange rate changes are classified according to three behavioral explanations: asymmetric hedging, hysteresis, and pricing-to-market (e.g., Koutmos and Martin, 2003; Muller and Verschoor, 2006a).

1. Asymmetric Hedging

Firms usually resort to asymmetric hedges, such as options, swaps, forward contracts, etc., in order to avoid adverse effects in the face of exchange rate shocks; see Miller and Reuer (1998) . For example, importers with net short positions may be willing to hedge against depreciation in the local currency, while remaining unhedged against appreciation in the local currency. On the other hand, exporters with net long positions are likely to hedge against the appreciation in the local currency yet may remain unhedged against the depreciation of that local currency. This asymmetric hedging behavior leads to an asymmetric impact on firms' cash flows.

2. Hysteresis

Another important source of asymmetry in exchange rate exposure is the so-called hysteretic behavior. A depreciation of the local currency may cause new exporters to enter the market, which will consequently limit the increase in profit brought about by depreciation. On the other hand, when the local currency appreciates, few of the existing firms will choose to exit the market if the sunk costs are high. Such a phenomenon is referred to as hysteresis in Baldwin (1988). It causes the reduction in the profits during the home currency's appreciation periods to exceed the increase in profits during the corresponding depreciation periods. This type of hysteretic behavior gives rise to asymmetric exposure.

3. Pricing-to-market

Pricing-to-market (PTM) describes the export price adjustment behavior that is based on the degree of competition in foreign markets. There are two objectives with such behavior in mind. The first is the market share objective (MSO). Using Japanese manufacturing data, Marston (1990) identifies asymmetric exposure whereby firms try to maintain market share by reducing export prices when the yen appreciates, but try to increase market share by holding export prices intact when the yen depreciates. The second objective is related to volume constraints (VC). Knetter (1994) points out that PTM may occur in the presence of volume constraints such as quotas or inadequate investment in marketing capacity. When export constraints exist, a potential increase in sales volume is restrained when the home currency depreciates. In such cases, exporters will increase their foreign currency prices to clear the market. If no similar constraint is required in the home country, then during the appreciation periods exporters will not exhibit PTM behavior.

III. *Symmetry Test in Correlations*

In this paper we apply a statistical test proposed by Hong et al. (2007) to examine the exchange rate exposure. The test is model-free and therefore has an advantage over earlier tests for asymmetric correlation, such as the test introduced by Ang and Chen (2002). In addition, no distribution assumption is required to adopt the test. In view of its robustness, the test is implemented to investigate asymmetric exchange rate exposure for various industries in Japan.

Let R_{1t} denote the index stock return of a particular industry at time t and R_{2t} the percentage change in exchange rate at time t. Both variables are standardized to have zero mean and unit variance. Following Login and Solnik (2001) and Ang and Chen (2002), we consider the exceedance correlation which is the correlation between the two variables when both of them are more than c standard-deviations away from their means, or specifically:

$$\rho^{+}(c)=corr(R_{1t}, R_{2t} \mid R_{1t}>c, R_{2t}>c). \tag{1}$$

Similarly, the exceedance correlation for a specified lower tail, denoted as $\rho^{-}(c)$, is:

$$\rho^{-}(c)=corr(R_{1t}, R_{2t} \mid R_{1t}<-c, R_{2t}<-c). \tag{2}$$

We are interested in testing whether correlations for the positive returns of two assets are the same as those for their negative returns. The null hypothesis of symmetric correlation is:

$$H_0:\rho^{+}(c)=\rho^{-}(c), \text{ for some } c\geq 0. \tag{3}$$

The alternative hypothesis is

$$H_A:\rho^{+}(c)\neq\rho^{-}(c), \text{ for some } c\geq 0. \tag{4}$$

Let $\hat{\rho}^{+}(c)$ and $\hat{\rho}^{-}(c)$ be the sample correlations under the tail restrictions. If the null is true, then the following $m\times 1$ difference vector must be close to zero:

$$\hat{\rho}^{+}-\hat{\rho}^{-}=[\hat{\rho}^{+}(c_1)-\hat{\rho}^{-}(c_1),...,\hat{\rho}^{+}(c_m)-\hat{\rho}^{-}(c_m)]'. \tag{5}$$

Let $T_c^{+}(T_c^{-})$ be the number of observations for which both R_{1t} and R_{2t} are simultaneously larger than c (less than $-c$). The sample means and variances of the two conditional series are:

$$\hat{\mu}_i^{+}(c)=\frac{1}{T_c^{+}}\sum_{t=1}^{T} R_{it}\,\mathbf{1}(R_{1t}>c,\ R_{2t}>c),$$

$$\hat{\mu}_i^{-}(c)=\frac{1}{T_c^{-}}\sum_{t=1}^{T} R_{it}\,\mathbf{1}(R_{it}<-c,\ R_{2t}<-c),$$

$$\hat{\sigma}_i^{+}(c)^2=\frac{1}{T_c^{+}-1}\sum_{t=1}^{T} [R_{it}-\hat{\mu}_i^{+}(c)]^2\mathbf{1}(R_{1t}>c,\ R_{2t}>c),$$

$$\hat{\sigma}_i^{-}(c)^2=\frac{1}{T_c^{-}-1}\sum_{t=1}^{T} [R_{it}-\hat{\mu}_i^{-}(c)]^2\mathbf{1}(R_{1t}<-c,\ R_{2t}<-c),$$

where $i=1,\ 2$ and $\mathbf{1}(\cdot)$ is the indicator function. The sample conditional correlations $\hat{\rho}^{+}(c)$ and $\hat{\rho}^{-}(c)$ can be obtained by:

$$\hat{\rho}^{+}(c)=\frac{1}{T_c^{+}-1}\sum_{t=1}^{T} X_{1t}^{+}(c)\,X_{2t}^{+}(c)\mathbf{1}(R_{1t}>c,\ R_{2t}>c), \tag{6}$$

$$\hat{\rho}^{-}(c)=\frac{1}{T_c^{-}-1}\sum_{t=1}^{T} X_{1t}^{-}(c)\,X_{2t}^{-}(c)\mathbf{1}(R_{1t}<-c,\ R_{2t}<-c), \tag{7}$$

where

$$X_{it}^{+}(c)=\frac{R_{it}-\hat{\mu}_i^{+}(c)}{\hat{\sigma}_i^{+}(c)},$$

$$X_{it}^{-}(c)=\frac{R_{it}-\hat{\mu}_i^{-}(c)}{\hat{\sigma}_i^{-}(c)},\ \forall i=1,\ 2.$$

Under the null of symmetry, Hong et al. (2007) show that $\sqrt{T}(\hat{\rho}^{+}-\hat{\rho}^{-})\xrightarrow{D} N(0,\ \Omega)$, for all possible true distributions of the data. A consistent estimator of Ω is given by:

$$\hat{\Omega}=\sum_{l=1-T}^{T-1} k(l/p)\hat{\gamma}_l, \tag{8}$$

where $\hat{\gamma}_l$ is an $m\times m$ matrix with the (i, j)-th element:

$$\hat{\gamma}_l(c_i,\ c_j)=\frac{1}{T}\sum_{t=|l|+1}^{T}\zeta_t(c_i)\zeta_{t-l}(c_j), \tag{9}$$

where

$$\zeta_t(c)=\frac{T}{T_c^{+}}[X_{1t}^{+}(c)X_{2t}^{+}(c)-\hat{\rho}^{+}(c)]\mathbf{1}(R_{1t}>c,\ R_{2t}>c)$$

$$-\frac{T}{T_c^-}[X_{1t}^-(c)X_{2t}^-(c)-\hat{\rho}^-(c)]1(R_{1t}<-c,\ R_{2t}<-c). \tag{10}$$

In addition, $k(\cdot)$ is the Bartlett kernel and p is the lag truncation order. The choice of p is determined by the data using the Newey and West (1994) procedure. Hong et al. (2007) propose the following statistic for testing for symmetry in correlation:

$$J_\rho = T(\hat{\rho}^+ - \hat{\rho}^-)'\,\hat{\Omega}^{-1}(\hat{\rho}^+ - \hat{\rho}^-). \tag{11}$$

Under the null hypothesis and some regularity conditions, Hong et al. (2007) show that:

$$J_\rho \xrightarrow{D} \chi_m^2. \tag{12}$$

If the null hypothesis of symmetry exposure is rejected, then we also consider the endogenous threshold model in order to analyze the relationship between asymmetric exchange rate exposure and industry characteristics. The threshold model is specified as:

$$R_{1t} = \beta_0 + \beta_1 R_{mt} + (\beta_2 + \beta_3 D_t)R_{2t} + \varepsilon_t, \tag{13}$$

where R_{mt} is the return on the market portfolio, and $D_t = 1$ if $R_{2t} > a$ and zero otherwise. Unlike previous asymmetry studies (e.g., Miller and Reuer, 1998, Di Iorio and Faff, 2000, Koutmos and Martin, 2003, and Muller and Verschoor, 2006a), we employ an endogenous threshold model. The threshold point, a, is estimated using the procedure proposed by Hansen (2000). The error term ε_t follows a GARCH(1,1) process, namely, the conditional variance of ε_t is specified as:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \sigma_{t-1}^2. \tag{14}$$

The coefficient β_2 measures exposure to exchange rate movements. For exporting firms, depreciations in the home currency will increase their profit margins. For importing firms, depreciations in the home currency will hurt their profits. Hence, the sign of β_2 can be either positive or negative, depending on industry characteristics. Exposure asymmetry can be measured by examining whether β_3 is statistically significant.

IV. *Empirical Results*

1. Data

The data we employ consist of the monthly returns on 33 Japanese industry indices obtained from the Pacific-Basin Capital Markets (PACAP) database.[1] As a proxy for the returns on the market portfolio, the Tokyo Stock Price Index (TOPIX) is used. To examine the asymmetric exposure to exchange rate fluctuations, we consider five currencies which are major trading countries with Japan to measure asymmetric exposure: the U.S. dollar (USD), the

[1] Several studies have found that the extent of estimated exposure is increasing in the return horizon; see Chow et al. (1997), Bodnar and Wong (2003), Dominguez and Tesar (2006), and Muller and Vershoor (2006b). Because short-horizon returns contain errors made by investors in forecasting the long-run effects of current exchange rates changes, we therefore use monthly returns in this paper.

Table 1. Symmetry Test For Industry Index And Exchange Rate

	J_ρ				
Industry Names	USD	BP	DM	CAD	AUD
Market	19.39	14.25	20.19	6.77	8.44
	(0.054)*	(0.220)	(0.042)*	(0.816)	(0.673)
Fishery & Agriculture	11.12	26.52	11.44	14.56	6.02
	(0.440)	(0.005)*	(0.460)	(0.203)	(0.872)
Mining	11.58	11.06	10.69	11.25	11.59
	(0.395)	(0.437)	(0.468)	(0.422)	(0.395)
Construction	18.03	9.75	14.95	10.86	10.99
	(0.081)*	(0.552)	(0.184)	(0.454)	(0.444)
Foods	19.10	10.59	15.67	10.55	9.91
	(0.059)*	(0.478)	(0.153)	(0.481)	(0.538)
Textiles & Apparels	18.21	9.63	13.49	7.77	10.33
	(0.076)*	(0.563)	(0.216)	(0.733)	(0.501)
Pulp & Paper	13.62	19.26	9.15	10.87	10.57
	(0.254)	(0.057)*	(0.607)	(0.453)	(0.479)
Chemicals	15.06	11.45	25.67	14.05	5.07
	(0.179)	(0.406)	(0.007)*	(0.230)	(0.927)
Pharmaceutical	**18.78**	**28.82**	10.98	**23.75**	9.20
	(0.065)*	(0.001)*	(0.444)	(0.013)*	(0.603)
Oil & Coal	19.89	14.22	14.60	12.81	22.14
	(0.046)*	(0.220)	(0.201)	(0.305)	(0.023)*
Rubber	28.13	14.44	10.56	16.13	8.38
	(0.003)*	(0.209)	(0.480)	(0.136)	(0.678)
Glass & Ceramics	26.21	15.29	18.67	12.06	9.04
	(0.005)*	(0.169)	(0.067)*	(0.361)	(0.618)
Iron & Steel	9.94	13.26	10.08	6.26	11.88
	(0.536)	(0.276)	(0.522)	(0.855)	(0.373)
Nonferrous Metals	9.67	20.49	8.46	8.95	7.48
	(0.559)	(0.039)*	(0.654)	(0.626)	(0.759)
Metal	12.10	23.08	22.72	8.40	14.61
	(0.356)	(0.017)*	(0.019)*	(0.676)	(0.201)
Machinery	6.72	12.53	15.23	3.51	14.04
	(0.871)	(0.325)	(0.171)	(0.982)	(0.231)
Electric Appliances	8.03	15.14	13.65	14.74	9.42
	(0.710)	(0.175)	(0.252)	(0.195)	(0.583)
Transportation Equipment	27.05	12.72	13.73	8.58	14.71
	(0.004)*	(0.311)	(0.247)	(0.660)	(0.196)
Precision Instruments	14.89	7.71	11.05	10.19	13.51
	(0.187)	(0.738)	(0.438)	(0.513)	(0.261)
Other Products	10.24	13.14	10.11	3.21	12.37
	(0.508)	(0.283)	(0.502)	(0.987)	(0.336)
Electric Power, Gas	16.91	4.98	15.30	31.43	19.57
	(0.110)	(0.931)	(0.168)	(0.000)*	(0.052)*
Land Transportation	11.47	10.38	14.56	18.48	10.77
	(0.404)	(0.496)	(0.203)	(0.071)*	(0.426)
Marine Transportation	13.00	14.87	12.34	8.31	12.43
	(0.219)	(0.188)	(0.338)	(0.684)	(0.332)
Air Transportation	12.85	21.42	10.37	11.44	14.77
	(0.320)	(0.029)*	(0.496)	(0.405)	(0.193)
Harbor Transportation Services	16.81	13.08	14.44	11.97	10.05
	(0.113)	(0.287)	(0.209)	(0.365)	(0.526)
Communication	13.31	13.55	10.30	7.29	10.20
	(0.273)	(0.258)	(0.503)	(0.776)	(0.512)
Wholesale Trade	15.20	9.10	4.38	21.50	15.05
	(0.173)	(0.612)	(0.957)	(0.028)*	(0.180)
Retail Trade	25.61	11.36	10.41	10.24	11.38
	(0.007)*	(0.413)	(0.493)	(0.508)	(0.411)
Banks	15.35	6.81	14.52	14.59	14.07
	(0.166)	(0.814)	(0.205)	(0.201)	(0.229)
Securities	15.74	12.25	21.15	18.56	11.07
	(0.150)	(0.344)	(0.031)*	(0.060)*	(0.386)
Insurance	31.79	15.38	12.55	14.38	12.26
	(0.000)*	(0.165)	(0.323)	(0.212)	(0.344)
Other Financing Business	16.42	19.60	11.17	11.14	11.52
	(0.126)	(0.051)*	(0.428)	(0.430)	(0.401)
Real Estate	**18.07**	17.01	**18.74**	**31.87**	10.11
	(0.079)*	(0.107)	(0.065)*	(0.000)*	(0.520)
Services	22.20	16.71	17.86	10.84	7.44
	(0.028)	(0.116)	(0.084)	(0.502)	(0.762)

1. The exchange rate is expressed in units of Japanese yen per foreign currency.
2. * The p values in parentheses are significant at the 10% level.

Table 2. Symmetry Test For Industry Index And Exchange Rate

	J_ρ				
Industry Names	USD	BP	DM	CAD	AUD
Market	27.70 (0.003)*	7.02 (0.783)	10.37 (0.497)	23.51 (0.015)*	14.26 (0.219)
Fishery & Agriculture	11.34 (0.415)	17.67 (0.090)*	12.40 (0.335)	19.150 (0.058)*	19.64 (0.051)
Mining	9.50 (0.576)	11.18 (0.428)	21.02 (0.033)*	17.61 (0.091)*	15.61 (0.156)
Construction	10.63 (0.475)	9.15 (0.606)	7.84 (0.727)	5.77 (0.888)	9.64 (0.563)
Foods	13.61 (0.252)	13.24 (0.278)	11.25 (0.422)	6.83 (0.813)	6.47 (0.810)
Textiles & Apparels	19.36 (0.055)*	10.14 (0.518)	8.45 (0.673)	8.37 (0.680)	9.66 (0.561)
Pulp & Paper	7.36 (0.769)	15.53 (0.160)	19.05 (0.060)*	18.09 (0.216)	34.89 (0.077)*
Chemicals	14.71 (0.196)	14.43 (0.030)*	9.40 (0.585)	6.06 (0.870)	9.50 (0.576)
Pharmaceutical	17.09 (0.105)	14.49 (0.210)	16.76 (0.115)	7.76 (0.735)	18.43 (0.072)*
Oil & Coal	9.99 (0.531)	6.32 (0.851)	14.24 (0.220)	13.60 (0.256)	8.24 (0.692)
Rubber	51.61 (0.000)*	20.08 (0.044)*	16.08 (0.138)	15.69 (0.153)	14.15 (0.226)
Glass & Ceramics	12.17 (0.351)	15.53 (0.160)	16.08 (0.809)	13.91 (0.238)	19.22 (0.057)*
Iron & Steel	10.63 (0.475)	10.12 (0.520)	22.80 (0.019)*	13.97 (0.235)	15.46 (0.164)
Nonferrous Metals	7.11 (0.790)	7.79 (0.731)	15.54 (0.158)	12.38 (0.336)	9.61 (0.566)
Metal	10.14 (0.144)	7.14 (0.787)	5.39 (0.911)	3.67 (0.979)	22.16 (0.023)*
Machinery	6.07 (0.868)	12.76 (0.309)	24.58 (0.011)*	17.79 (0.087)*	9.68 (0.559)
Electric Appliances	10.11 (0.520)	16.56 (0.122)	4.81 (0.940)	20.23 (0.040)*	22.45 (0.021)*
Transportation Equipment	14.26 (0.219)	11.23 (0.429)	10.45 (0.491)	13.35 (0.274)	6.74 (0.820)
Precision Instruments	19.64 (0.051)*	16.17 (0.135)	10.17 (0.516)	10.46 (0.485)	12.14 (0.353)
Other Products	15.61 (0.156)	5.15 (0.924)	15.80 (0.149)	16.88 (0.110)	5.14 (0.924)
Electric Power, Gas	9.64 (0.563)	21.62 (0.027)*	16.44 (0.126)	12.53 (0.343)	13.11 (0.286)
Land Transportation	6.47 (0.810)	4.32 (0.960)	14.22 (0.221)	5.70 (0.892)	21.78 (0.026)*
Marine Transportation	9.66 (0.561)	19.12 (0.059)*	13.37 (0.270)	14.22 (0.220)	8.81 (0.640)
Air Transportation	**34.89** (0.000)*	**19.79** (0.048)*	14.02 (0.232)	**27.72** (0.000)*	13.38 (0.269)
Harbor Transportation Service	9.50 (0.576)	16.15 (0.136)	16.53 (0.123)	19.96 (0.054)*	11.79 (0.397)
Communication	18.43 (0.072)*	10.25 (0.508)	15.53 (0.160)	9.47 (0.586)	7.75 (0.753)
Wholesale Trade	8.24 (0.692)	12.17 (0.351)	7.49 (0.758)	8.82 (0.646)	12.45 (0.331)
Retail Trade	14.15 (0.226)	11.57 (0.397)	11.84 (0.376)	4.77 (0.943)	9.59 (0.568)
Banks	19.22 (0.057)*	8.51 (0.667)	9.12 (0.611)	10.59 (0.486)	9.85 (0.544)
Securities	15.46 (0.164)	16.09 (0.134)	19.20 (0.058)*	10.81 (0.464)	17.38 (0.097)*
Insurance	9.61 (0.566)	7.97 (0.716)	8.43 (0.675)	3.94 (0.975)	5.94 (0.878)
Other Financing Business	22.16 (0.023)*	8.58 (0.660)	27.72 (0.004)*	14.21 (0.224)	17.25 (0.101)
Real Estate	9.68 (0.559)	21.00 (0.033)*	16.56 (0.122)	7.06 (0.793)	15.20 (0.174)
Services	22.45 (0.021)*	17.08 (0.106)	14.31 (0.216)	14.84 (0.194)	14.59 (0.202)

1. The exchange rate is expressed in units of foreign currency per Japanese yen
2. * The *p* values in parentheses are significant at the 10% level

British Pound (BP), the German Mark (DM), the Canadian dollar (CAD), and the Australian dollar (AUD). The observations total 228 from January 1983 to December 2001.

2. Testing for Asymmetry Correlations

The asymptotic theory provides little guidance for choosing the exceedance levels. In this section we choose a set of eleven exceedance levels: $c_1=0$, $c_2=0.05$, $c_3=0.1$, …, $c_9=0.4$, $c_{10}=0.45$, and $c_{11}=0.5$. Table 1 provides the results of the symmetry correlation test for different industries. In the test, R_{1t} is the index stock return of a particular industry and R_{2t} is the rate of depreciation in yen against a particular foreign currency. Under the null hypothesis, $\hat{\rho}^+$ means that the index returns go up and the yen depreciates at the same time, while $\hat{\rho}^-$ means that index returns go down and the yen appreciates at the same time. In total, around 21% (35/170) of the cases examined exhibit significant asymmetric exposure at the 10% level. Twelve industries exhibit asymmetric exposures for the YEN/USD exchange rate, but only two industries have asymmetric exposures for the YEN/AUD exchange rate. In particular, as a proxy for the market portfolio, the Tokyo Stock Price Index (TOPIX), exhibits significant asymmetric correlations for both the USD and DM. This finding is not surprising, since the United States and Germany are the two biggest exporting countries.

With R_{1t} as the index stock return and R_{2t} as the rate of depreciation in yen, the test can only detect whether the positive correlations between stock returns and the yen depreciation rates are asymmetric, if at all. For importing firms, the depreciation in the yen might hurt their profits. Hence, the relevant alternative hypothesis is to test for possible asymmetric negative correlation between the stock returns and the yen depreciation. We therefore conduct the test again by defining R_{2t} as the rate of appreciation in yen and report the corresponding results in Table 2. Consequently, $\hat{\rho}^+$ means that the index returns go up and the yen appreciates together, while $\hat{\rho}^-$ means that both returns move downwards. Similarly, the percentage of significant asymmetric exposure is 21% (36/170) for all cases examined. Nine industries exhibit asymmetric exposures for the USD/YEN exchange rate. The TOPIX also exhibits a significant asymmetric correlation for the USD as was the case in Table 1. Based on the results in Table 1 and 2, there are significant asymmetric responses in stock returns to exchange rate changes in the pharmaceutical, real estate, and air transportation industries.[2]

3. Asymmetric Exposures and Industry Characteristics

In this section we use the threshold model with the GARCH effect to examine whether the three industries, in the pharmaceutical, real estate, and air transportation industries, reject the null hypothesis of the symmetry test in Tables 1 and 2. Table 3 presents the exchange rate exposure coefficient estimates. For the pharmaceutical industry, the threshold value a is -0.0127 for the USD, 0.0234 for the BP, -0.02823 for the DM, -0.00848 for the CAD, and -0.00121 for the AUD. For the USD, BP, and DM, the asymmetric exposure coefficients, i.e., β_3, are significantly negative. In order to keep their market shares, pharmaceutical firms in Japan may exhibit asymmetric responses with respect to the appreciation and depreciation of the yen.[3] The asymmetric response can be explained by the market share objective (MSO)

[2] The industries considered exhibit significant asymmetric exposure with respect to at least three of the currencies.

TABLE 3. EXCHANGE RATE EXPOSURE COEFFICIENT ESTIMATES FOR INDUSTRY INDEXES

	β_1	β_2	β_3	a
Pharmaceutical				
USD	0.58 (0.01)*	3.00 (0.04)*	-3.12 (0.07)*	-0.0127
BP	0.29 (0.02)*	2.31 (0.00)*	-5.11 (0.00)*	0.0203
DM	0.13 (0.46)	0.98 (0.22)	-2.96 (0.07)*	-0.0282
CAD	0.78 (0.00)*	0.13 (0.82)	0.20 (0.63)	-0.0084
AUD	0.65 (0.00)*	0.15 (0.12)	-0.17 (0.42)	-0.0012
Real Estate				
USD	1.13 (0.00)*	0.06 (0.66)	-0.41 (0.06)*	-0.0729
BP	1.19 (0.00)*	0.07 (0.60)	-0.42 (0.09)*	0.0315
DM	1.16 (0.00)*	0.01 (0.96)	0.11 (0.68)	0.0066
CAD	1.17 (0.00)*	0.23 (0.21)	-0.44 (0.04)*	0.0055
AUD	1.17 (0.00)*	0.02 (0.82)	-0.13 (0.53)	0.0170
Air Transportation				
USD	0.80 (0.00)*	-0.13 (0.29)	0.42 (0.08)*	-0.0519
BP	0.82 (0.00)*	-0.09 (0.71)	0.29 (0.27)	0.0539
DM	0.94 (0.00)*	-0.07 (0.63)	0.46 (0.05)*	-0.0556
CAD	0.80 (0.00)*	-0.02 (0.85)	0.18 (0.36)	-0.0496
AUD	0.94 (0.00)*	-0.31 (0.08)*	0.65 (0.01)*	-0.0020

* The p values in parentheses are significant at the 10% level.

behavior as an optimal strategy to avoid losing market share when the exchange rate changes.

Hysteresis may also contribute to the asymmetric response in the pharmaceutical industry due to high sunk costs such as research and development (R&D) and advertising. The pharmaceutical industry has the highest R&D expenditure in the manufacturing industry, because such expenditure can be spread across a wide range of technology; see, for example, Sutton (1991) and Schmalenesee (1992) for an in-depth discussion. If the yen depreciates dramatically, then new entrants would be attracted to the pharmaceutical industry in spite of the high entry cost. However, if the exchange rate reverses later, then fewer firms will choose to exit. Hence, the hysteretic behavior can also lead to asymmetric exchange rate exposure.

As indicated by the results in Table 3, the real estate industry is characterized by asymmetric exposure to the USD, BP, and CAD, and the asymmetric exposure coefficients of these currencies are significantly negative. Such asymmetric exposure can result from the asymmetric hedging behavior. Firms with net short positions are likely to hedge against the yen's depreciation, but remain unhedged against the yen's appreciation. Even though the real estate industry is non-tradable, foreign investors who buy Japanese real estate might adopt hedging behavior to avoid yen depreciation risk.[4] As a result, we shall observe negative correlations when the yen depreciates. This is consistent with our finding in Table 3. Namely, in the real estate industry, firms usually take a one-sided hedging bet on the USD, BP, and

[3] According to Matraves (1999), Sankyo and Takeda are the two leading Japanese pharmaceutical firms and were ranked among the top 20 in terms of global pharmaceutical market share in 1995.

[4] The asymmetric exchange rate exposure can exist even in a non-tradable industry such as real estate. Because foreign investors are likely to use hedging tools, such as currency options, forward contracts and currency swaps to avoid home currency depreciation risk. This view was confirmed by Ziobrowski et al. (1997) with U.S. data and Liu and Mei (1998) with cross-country data.

CAD to avoid adverse effects.

The asymmetric exposure in the real estate industry may not be a unique case to occur in Japan only. Other country studies on exchange rate exposure had reported results for a broader finance industry, which includes finance, insurance, and real estate. Their findings in the finance industry also indicate significant asymmetric exchange rate exposure. For instance, Koutmos and Martin (2003) document significant asymmetric exchange rate exposure in the U.S. financial equity returns. Muller and Vershoor (2006a) study multinational data and find significant currency risk exposure effect in the finance sector. If the asymmetry in the finance industry is partially caused by the asymmetric effect in the real estate industry, then such phenomenon is not specific to Japan only.

For the air transportation industry, we find that the asymmetric exposure coefficients β_3 are both significant and negative for the USD, DM, and AUD in Table 3. The reduction in profits during the yen's depreciation is larger than the increase in profits during the yen's appreciation. James and Anming (1990) find that the air transportation industry exhibits Cournot behavior. As we know, a firm in an oligopolistic market always seeks to expand its market share in the short run and to maximize its profits in the long run. Because large market shares represent high market power, the oligopolists can raise the mark-up rate on pricing. Therefore, firms in the air transportation industry will take PTM with MSO in order to maintain or increase their market shares and profits under exchange rate swings. In addition, the air transportation industry has high sunk costs such as expenditures on aircraft and advertising. This also leads to the hysteretic behavior and gives rise to asymmetric exchange rate exposure.

V. *Conclusions*

This paper demonstrates that the degree of exchange rate exposure is asymmetric during times of currency appreciation and depreciation. We use the model-free test of Hong et al. (2007) to detect asymmetric correlations between the returns of industry indices and exchange rates. Based on the results for 33 Japanese industries, we find that the pharmaceutical, real estate and air transportation industries exhibit asymmetric correlations. Furthermore, when we examine these industries using the threshold model with the GARCH effect, it is evident that these asymmetric exposures are consistent with the pricing-to-market and hysteretic behavior in the pharmaceutical and air transportation industries and with the hedging behavior in the real estate industry. Therefore, the asymmetric exposures are industry characteristic-based.

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