Multiple Asymmetries and Exchange Rate Exposure Management*

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Abstract

Reliable and consistent estimates of the sensitivity of stock returns to the changes in exchange rates (exchange rate exposure of stock returns) is an essential piece of information needed in exchange rate exposure management and government policy implementation towards financial markets in a country. Obtaining reliable estimates may be hindered by the negligence of the stylised facts associated with the exposure process. Existence of asymmetries in both stock returns and volatility of stock returns underlying exchange rate exposure are some of those stylised facts that seem to be seriously neglected in the current studies of exchange rate exposure. This paper analyses three types of asymmetries using a sample of 50 Japanese firms. The main contribution of the paper to the literature of exchange rate exposure management and policy making is two fold: (a) with an appropriate model, it simultaneously examines both sign (arising from appreciations and depreciations) and magnitude (arising from small and large changes in exchange rate) asymmetries of exchange rate exposure of stock returns and the asymmetry of volatility of stock returns underlying the exposure process; (b) in line with our objective of generating more reliable estimates that can be used for exchange rate management of firms, the study is carried out at the firm level. While the presence of sign and magnitude asymmetries can be supported by moderate evidence, our results show strong evidence for the presence of asymmetric volatility underlying exchange rate exposure of Japanese firms. We believe that these results have direct implications for exchange rate exposure management and government policy implementation towards financial markets.

Key words: Exchange rate exposure management, Asymmetric exchange rate exposure, Asymmetric volatility

JEL Classification: F3, G12, G18
I. Introduction

A majority of studies in exchange rate exposure literature, either implicitly or explicitly, assume that the exchange rate exposure of stock returns is symmetric (a) between appreciations and depreciations and (b) between small and large exchange rate changes. However, a few studies cite evidence for sign asymmetry (arising from different responses of firms/sectors to appreciations and depreciations) and magnitude asymmetry (arising from different responses of firms/sectors to small and large changes in exchange rate) in exchange rate exposure. Kanas (1997) and Koutmos and Martin (2003a) investigate whether exchange rate exposure is asymmetric between currency appreciations and depreciations. Both studies report that there exists enough evidence to argue that exchange rate exposure is asymmetric in its sign at least in the case of a considerable number of cases. For instance, Koutmos and Martin (2003a) conclude that about 40 percent of the country-sectors examined by them show significant exchange rate exposure and that the exposure of 40 percent of those sectors are asymmetric. Investigating the same asymmetry concept, Miller and Reuer (1998) conclude that, although the evidence for asymmetric exposure is limited, there is almost no evidence to conclude that firms are exposed in a symmetric fashion. De Iorio and Faff (1999) cite evidence in support of the exchange rate asymmetry between small and large exchange rate changes. However, they report mixed results. Andren (2001) who looks into both sign and magnitude asymmetries in macroeconomics exposure of stock returns in general (the study includes a number of macroeconomic variables such as exchange rate, interest rate and inflation) cites strong evidence for the existence of such asymmetries. Priestley and Odegaard (2002), assuming that there is a non-linear component of exchange rate exposure as well, include a quadratic term of exchange rate change in the augmented CAPM formulation. They report that the inclusion of quadratic term improves the explanatory power of stock returns over and above that of linear exposure.

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1 Exchange rate exposure is defined as the sensitivity of stock prices (or firm value) to the changes in exchange rate (Adler and Dumas, 1984; Heckman, 1983).

2 However, Andren (2001) does not include the relevant variables in the same model and uses two separate models to capture these two types of asymmetries.
Why does one have to worry about asymmetries in exchange rate exposure of stock returns? If asymmetries actually exist in exchange rate exposure of stock returns and volatility of stock returns, decision making of all the parties involved in the exposure process must be reconsidered in the context of those asymmetries. The parties concerned involve profit-seeking individuals and portfolio managers who invest in stocks, firms who would like to hedge against exchange rate exposure, financial engineers who design financial instruments and governments that seek smooth functioning of financial markets and resultant economic development. For instance, if asymmetries actually exist in the exposure process, a firm may prefer to use a particular type of financial instruments in hedging against exchange rate exposure. Then the government has to come up with appropriate policies to develop markets for such financial instruments and conduct smooth functioning in those markets in a pro-growth manner. Taking multiple asymmetries involved in the exposure process into account will generate two extremely important pieces of information needed in exchange rate exposure management and policy implementation decisions, namely, (a) the degree of asymmetry in returns and/or volatility of returns and (b) reliable exposure coefficients.

Motivation behind this study is twofold. First, to date, there is no study that considers the asymmetry in both first and second moments at the same time to generate more reliable exposure estimates. For instance, while Andren (2001), De Iorio and Faff (1999), Koutmos and Martin (2003a), Miller and Reuer (1998) etc show evidence of asymmetric exchange rate exposure alone, another set of studies like Kanas (2000), Yang (2003), Giurda and Tzavalia (2004) considers asymmetry in volatility of stock returns only. Second, although the hedging related research badly needs firm-level analyses, there are no firm level studies which examine the asymmetry in volatility of stock returns underlying exchange rate exposure. For instance, Kanas (2000), Yang (2003), Giurda and Tzavalia (2004) analyse asymmetry in volatility of stock returns related to exchange rate exposure at country level. In this paper, we suggest a firm-level model that captures both sign (arising from appreciations and depreciations) and magnitude (arising from small and large changes in exchange rates) asymmetries in stock returns together with asymmetry in volatility of stock returns underlying exchange rate exposure.
II. Asymmetry in exchange rate exposure of stock returns

The view that exchange rate exposure is symmetric between both appreciations and depreciations and between large and small changes in exchange rate is valid only if the firms act as passive agents as exporters and/or importers. However, in reality, firms do respond to the macroeconomic changes that they are confronted with and, as a result, their behaviour towards domestic currency appreciations and depreciations and/or small and large changes in exchange rate is not the same. In general, these asymmetries stem from the microeconomic behaviour of the firms which may make attempts to exploit opportunities and avoid adverse effects in response to various macroeconomic changes.

There exists a rich stream of literature which establishes asymmetric relationships between corporate profits and exchange rate changes (Froot and Klemperer, 1989; Knetter, 1994; Krugman, 1987, to name a few). As the basic assumption underlying any analysis of exchange rate exposure of stock returns is that a firm’s stocks (firm value) adequately represent the firm’s discounted values of all expected future net cash flows (or profits), we can safely use the arguments in the above studies to explain the asymmetries in exchange rate exposure of stock returns. There are a few behavioural characteristics of firms with which one can explain the asymmetric nature of exchange rate exposure. These characteristics include pricing-to-market, hysteretic behaviour, asymmetric hedging behaviour and behaviour related to magnitude asymmetries.

Pricing-to-market

One important source of asymmetry of exchange rate exposure is pricing-to-market behaviour of firms which may take either of two forms: pricing-to-market with the intention of enhancing market share and pricing-to-market under volume constraints. As Knetter (1994) summarises, the former view assumes that the firms are maximisers of their market share. When local currency appreciates, an exporter does not want to pass on

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3 There are a few studies that develop models to explain pricing-to-market behaviour of firms. See, for instance, Froot and Klemperer (1989), Knetter (1994), Krugman (1987), Marston (1990).
the effects of such an appreciation to buyers by increasing foreign prices of their goods. Most probably, they let its mark-up decrease in order to maintain a competitive price in foreign markets. They do this to avoid the risk of losing the market share that may be brought about by the dumping attempts of their competitors in other countries. However, when local currency depreciates this process may not reverse symmetrically (i.e. they may not be tempted to increase their mark-ups). Instead, driven by the market share maximising objective, they may maintain the mark-up at the same level without attempting to increase it and pass the benefits of depreciation towards foreign prices of their goods by reducing those prices. Thus, their profits would increase to a lesser degree during depreciation periods than decrease in appreciation periods.

“Pricing-to-market under volume constraints” view assumes that, in the presence of volume constraints such as quota or inadequate investment in marketing capacity (known as “bottlenecks”), the above mechanism works in the other direction. In such a situation, even if the domestic currency depreciates, the presence of the constraints will eliminate the possibility of increasing sales volume. Therefore, exporters would increase their foreign currency prices to clear the market (i.e. they are not interested in passing the benefits of depreciation to the buyers and may increase their mark-ups). During appreciations there is no such constraint and exporters may not use p-t-m and may let the appreciation be reflected in foreign prices (i.e. they do not reduce foreign prices).

**Hysteresis**

If the depreciation of domestic currency persists for a considerably lengthy period, a number of new exporting firms (both local and foreign) may enter the market to make the advantage of weakened domestic currency. Therefore, the profits of the existing exporting firms may not increase to the degree that would occur if the new entrants had not entered. If this period of depreciation is followed by a period of appreciation, one may expect that the new firms will quit the market and the same process will reverse symmetrically. However, the reality is that, given the sunk costs that the new firms

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4 See Baldwin (1988) and Dixit (1989) for this type of hysteresis models.
incurred, they are not in a position to just quit the market. These firms are more likely to stay in the market with meagre profit margins or even losses in such periods of appreciation. This gives birth to an asymmetry in exchange rate exposure. The reduction in profits during appreciations is larger than the increase in profits during depreciations.

*Asymmetric hedging*

Firms’ liking to exploit opportunities and avoid adverse effects in the face of various macroeconomic changes is well reflected in their hedging behaviour. As a number of writers point out, currency options are non-linear instruments that may provide downside protection with the opportunity to exploit upside potential. According to Miller and Reuer (1998), who use a two separate terms of exchange rate change for appreciations and depreciations in their model, option theory suggests that exposure coefficients may vary depending on whether local currency depreciates or appreciates. Holding a call option on an asset that appreciates with the real value of local currency may be consistent with a positive exposure coefficient when local currency appreciates but no exposure when local currency depreciates. On the other hand, holding a put option on an asset that appreciates with the real value of local currency may be consistent with a negative exposure coefficient when local currency depreciates but no exposure otherwise (Miller and Reuer, 1998). As Andren (2001) put it, the active use of “real or financial options would mean that market-value exposures would be larger to beneficial macroeconomic changes than to adverse [ones], since options allow hedging adverse changes and exploiting beneficial changes”.

*Asymmetry brought about by the magnitude of exchange rate change*

Not each and every exchange rate change is followed by decisions related to pricing-to-market, hysteretic or asymmetric hedging behaviour of firms (i.e. actions that would lead to asymmetries in exchange rate exposure arising from appreciations/depreciations). For instance, in the case of hysteresis, firms may not enter a new market unless the
depreciation is relatively large. Firms may not exercise hedging through “real options” if exchange rate changes are negligibly small. For the sake of easy illustration of the point in question, we can say that the firms will actively respond to the exchange rate changes, only if it is greater than a certain threshold, say z. The magnitude of z may depend on the factors like size of the firm, industry to which it belongs, its past experience etc. These unequal responses of the firms to small and large exchange rate changes give birth to another kind of asymmetry, namely the magnitude asymmetry of exchange rate exposure.

III Asymmetry in volatility of stock returns underlying exchange rate exposure

The main instrument with which the asymmetry in volatility of stock returns is explained is known as the leverage effect which is now common knowledge in finance literature. The negative return shock resulting from a bad news increases a firm’s debt-equity ratio (commonly known as leverage ratio) which in turn leads to higher volatility. On the other hand, the positive return shock resulting from a good news will lower the leverage ratio which in turn leads to low volatility levels.

However, the picture is not that straightforward when it turns to the volatility of stock returns underlying exchange rate exposure. For instance, at national/country level, it is really difficult to say whether depreciation is actually a good news or a bad news. This is because an aggregate stock index consists of various types of firms like exporters, importers, import competitors, producers of non-traded goods, internationally priced input users etc. whose profits are affected by exchange rate changes in different ways. However, at firm level, there may be some chance to use the leverage effect argument. As Bodnar and Gentry (1993) classify, exporters and import competitors benefit from depreciation of local currency while importers, producers of non-traded goods and internationally priced input users are adversely affected by it. Accordingly, we know that depreciation is a good news for an exporter, but a bad news for an importer. Still, if one

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5 The term “real options” represents “all types of operating or strategic flexibility [including] the ability of a firm to shift production location or factors of production, to shift marketing activities between sales markets and market segments, and to shift level of competitive rivalry” Andren (2001).
firm plays more than one of the above roles, again the effect may be unclear. On the other hand, as elaborated in Jayasinghe and Premaratne (2004), a firm’s indirect exposure effect is partly dependent on the correlation between the exchange rate changes and market returns and, if the indirect effect is sufficiently large, it may even totally offset the direct exposure effect⁶. This makes one’s task of judging the underlying mechanism more difficult.

Interestingly, as Maghrebi et al (2004), a study that cites evidence for existence of asymmetry in volatility of stock returns in response to exchange rate changes at country level, put it “whether depreciation of domestic currency should be viewed as a good news or a bad news is an open question”. Kanas (2000), Yang (2003), Giurda and Tzavalia (2004) also cite evidence for the existence for exchange rate related volatility asymmetry in stock returns at national/country level. This implies that although the mechanism through which it comes into being is unclear (or still remains unresolved), asymmetry in volatility of stock returns underlying exchange rate changes is as one of the stylized facts associated with the exposure process. For the same reason we take the asymmetry in volatility of stock returns underlying exchange rate exposure also into account in the suggested model developed in the next section.

IV The model

In order to capture both sign asymmetry (arising from different responses of firms to appreciation and depreciation) and magnitude asymmetry (arising from different responses of firms to small and large changes in exchange rate) of exchange rate exposure, we suggest a further extended version of augmented CAPM specification:

\[ r_{1,t} = \beta_0 + \beta_1 r_{m,t} + (\beta_2 + \beta_3 D_{\text{sign}} + \beta_4 D_{\text{mag}}) r_{x,t} + \epsilon_{1,t} \]  

⁶ In terms of the suggested model elaborated in the next section, direct and indirect exposure effects are \( \beta_2 \) and \( \delta \beta_1 \) respectively.
where $r_{i,t}$ is return on firm i’s stock at time period t; $r_{m,t}$ is return on market portfolio at time period t; $r_{x,t}$ is percentage change in exchange rate at time period t; $D_{\text{sign}} = 1$ if $r_{x,t} < 0$ and 0 otherwise; $D_{\text{mag}} = 1$ if $|r_{x,t}| > z$ and 0 otherwise; $z$ is the threshold level of exchange rate change for which firms are assumed to begin responding (in this analysis we consider 0.5% as this threshold level).

In order to combine both direct and indirect exposure effects, we run a side regression using market returns on exchange rate changes.

$$r_{m,t} = \delta_0 + \delta_1 r_{x,t} + r_{m,t}^e \quad (2)$$

where $r_{m,t}^e$ is known as orthogonalized market returns or market residuals. Substituting (2) into (1) one can obtain:

$$r_{i,t} = \beta_0^* + \beta_1^* r_{m,t} + \left(\beta_2^* + \beta_3^* D_{\text{sign}} + \beta_4^* D_{\text{mag}}\right) r_{x,t} + \epsilon_{i,t} \quad (3)$$

where $\beta_2^* = \delta_1 \beta_1 + \beta_2$ and $\beta_0^* = \beta_0 + \beta_1 \delta_0$.

Following Jayasinghe and Premaratne (2004), in order to capture a few stylized facts associated with exchange rate exposure process (these include time-varying volatility, non-normal error term distributions etc.) we employ a GARCH model whose error term is assumed to be t-distributed. To accommodate asymmetry in volatility of stock returns, an important stylized fact underlying the exposure process, a GJR version of GARCH modelling is used. More specifically, we use an orthogonalized GJR-GARCH(1,1)-t model with two dummy-type variables that represent two asymmetries in the mean equation.
\[ r_{i,t} = \beta_0^* + \beta_1 r_{m,t}^* + \left( \beta_2^* + \beta_3 D_{sign} + \beta_4 D_{mag} \right) e_{i,t} + \varepsilon_{i,t} \]  

(3)

\[ \varepsilon_t \mid \psi_{t-1} \sim f_\nu(\varepsilon_t \mid \psi_{t-1}) \]  

(4)

\[ r_{m,t} = \delta_0 + \delta_1 \psi_{t-1} + r_{m,t-1}^{*} \]  

(5)

\[ h_{i,t} = c_{0,i} + a_t \varepsilon_{i-1}^2 + \gamma_t e_{t-1}^2 d_{t-1} + b_t h_{i,t-1} \]  

(6)

where \( h_{i,t} \) is conditional variance of the error term from (3); \( \psi_{t-1} \) is information available at time \( t-1 \); \( d_{t-1} \) is equal to 1 if \( \varepsilon_t \) is negative and 0 otherwise; and \( \nu \) is degrees of freedom of \( t \) distribution, an additional parameter that explains the tail thickness of the distribution. Usual constraints related to GARCH models like \( c > 0 \), \( a > 0 \), \( b > 0 \), \( a + \gamma > 0 \) and \( \frac{1}{2} \gamma + a + b < 1 \) apply. If \( \gamma \) is statistically significant, that implies the existence of asymmetric volatility of stock returns underlying exchange rate exposure.

For a given value of market returns, exposure coefficient is \( \beta_2^* \), if \( r_x > 0 \) and \( |r_x| < z \). It would be \( \left( \beta_2^* + \beta_4 \right) \), if \( r_x > 0 \) and \( |r_x| > z \). Exposure coefficient will become \( \left( \beta_2^* + \beta_3 \right) \), if \( r_x < 0 \) and \( |r_x| < z \). Finally, the exposure coefficient will be equal to \( \left( \beta_2^* + \beta_3 + \beta_4 \right) \), if \( r_x < 0 \) and \( |r_x| > z \) (see table 01 for descriptions). According to Koutmos and Martin (2003a)\(^7\), this type of specification provides us with a direct test for asymmetries in both magnitude and sign and the test for asymmetries is equivalent to testing whether \( \beta_3 \) and/or \( \beta_4 \) are statistically significant.

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\(^7\) Koutmos and Martin (2003a) raise this argument for their model which tests only for sign asymmetry.
Table 01
Parameter representation of various sign and magnitude changes in exchange rate in the suggested model

<table>
<thead>
<tr>
<th>Nature of the change in exchange rate</th>
<th>Parameter representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A depreciation less than the threshold level (i.e. ( r_x &gt; 0 ) and (</td>
<td>r_x</td>
</tr>
<tr>
<td>A depreciation greater than the threshold level (i.e. ( r_x &gt; 0 ) and (</td>
<td>r_x</td>
</tr>
<tr>
<td>An appreciation less than the threshold level (i.e. ( r_x &lt; 0 ) and (</td>
<td>r_x</td>
</tr>
<tr>
<td>An appreciation greater than the threshold level (i.e. ( r_x &lt; 0 ) and (</td>
<td>r_x</td>
</tr>
</tbody>
</table>

\( z \) : threshold level of exchange rate change at which firms are supposed to begin responding

For the argument that exchange rate exposure associated with large changes is greater than that of small changes to hold, \( \beta_4 \) must be positive. However, \( \beta_2 \) and \( \beta_3 \) can be either negative or positive depending on whether the firm in question is an exporter or an importer. Accordingly, there may be a number of combinations of \( \beta_2 \) and \( \beta_3 \) which may imply various sources of sign asymmetry. In order to elaborate on this issue, we adopt the classification developed in Koutmos and Martin (2003a) which is depicted in Table 02.

Table 02
Sources of sign asymmetry of exchange rate exposure

<table>
<thead>
<tr>
<th>( \beta_3 &gt; 0 )</th>
<th>( \beta_3 = 0 )</th>
<th>( \beta_3 &lt; 0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Net exporters</td>
<td>- Net exporters or importers</td>
<td>- Net importers</td>
</tr>
<tr>
<td>- Pricing-to-market with market share objective</td>
<td>- No exposure</td>
<td>- Asymmetric hedging</td>
</tr>
<tr>
<td>- Hysteresis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \beta_3 = 0 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Net exporters</td>
<td>- Net importers or importers</td>
<td>- Net importers</td>
</tr>
<tr>
<td>- Symmetric exposure</td>
<td>- No exposure</td>
<td>- Asymmetric hedging</td>
</tr>
<tr>
<td>( \beta_3 &lt; 0 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Net exporters</td>
<td>- Net importers or importers</td>
<td>- Net importers</td>
</tr>
<tr>
<td>- Pricing-to-market under volume constraints</td>
<td>- No exposure</td>
<td>- Asymmetric hedging</td>
</tr>
<tr>
<td>- Asymmetric hedging</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Adopted from Koutmos and Martin (2003a)
V The data

All data is obtained from DataStream. We focussed on electronics and electrical goods sector in Japan. The reason for selection of firms in this sector is their high international involvement. 50 large firms have been selected. Market portfolio is assumed to be represented by Nikkei 225, the overall stock index in Japan. All stock returns and market returns are expressed in yen.

A trade-weighted exchange rate is used to measure the exchange rate changes. Exchange rates are expressed as the local currency price of foreign currency: i.e. an increase in the index shows depreciation of local currency. Following most of the previous studies, changes in nominal exchange rates have been used. Justification of using nominal exchange rates are based on a few valid arguments: (a) “using the real exchange rates would assume that financial markets instantaneously observe the inflation rates that are necessary for calculating the real exchange rate” (Bodnar and Gentry, 1993); (b) it is a well established observation that there exists a high correlation between the changes in nominal and real exchange rates (Bodnar and Gentry, 1993; Khoo, 1994).

Exchange rate exposure was estimated using daily data. It is argued that exchange rate exposure is not well reflected in daily returns. Infrequent trading, bid-ask spread, and asynchronous pricing are some of the criticisms levelled at the use of daily data in estimating exchange rate exposure (Patro et al, 2002). However, we decided to rely on daily data as we use GARCH family models which are assumed to be good at capturing volatility associated with high frequency data. Sample period extends from June.1989 through May 2004. It provided us with 3910 observations. Exchange rate exposure coefficients were estimated using BHHH algorithm.

Firm was selected as the unit of analysis for a few important reasons. First, given the fact that even the firms within the same industry are not homogenous and may have different exposure coefficients (within the same industry various firms may be exposed in opposite ways), although the industry-wide exposure is really high, individual exposure effects may be averaged out with the aggregation of the firms’ returns. Also, at industry level
most return indices are value-weighted, meaning that more weights are allocated to large firms. If small firms are more exposed to exchange rate changes, this will again misjudge the true level of exposure (Domínguez and Tesar (2001). Second, since an industry may nest both importers and exporters, asymmetry of both first and second moments of stock returns associated with exchange rate changes may also be averaged out at industry level. So, the asymmetry, if at all, can best be captured at the firm level. Finally, our objective is to suggest a means to find more realistic and reliable estimates that are useful in exchange rate management and investment decisions of firms, an area where the key institution in question is the firm.

VI Results and major findings

Like the previous studies such as Chamberlin et al (1997), De Iorio and Faff (1999), Koutmos and Martin (2003b) that rely on daily data to estimate exchange rate exposure, we also found somewhat strong evidence for the presence of exchange rate exposure. When orthogonalized GARCH(1,1)-t model (which does not accommodate any of those three asymmetries) was used to estimate exchange rate exposure, twenty eight firms (or 56% of the total sample) display exposure to exchange rate changes at 5% level of significance. However, when the estimation of exposure coefficients is done with the suggested model which is assumed to capture all asymmetries, the number of firms with statistically significant exposure coefficients reduces to fourteen (a reduction by 50% of the initial number). Five cases out of those fourteen (or 35.14 % of the firms that are exposed to exchange rate changes) possess statistically significant $\beta_3$, meaning that there exists sign asymmetry among a considerable number of exposed firms. On the other hand, 6 cases out of it possess statistically significant $\beta_4$, meaning that 42.86 % of the total number of firms that have been exposed to exchange rate changes show magnitude asymmetry. However, only one firm displays both asymmetries together (or statistically significant $\beta_3$ and $\beta_4$). Thirty eight firms (or 76% of the total sample) show asymmetry

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8 Selected threshold level to check whether there is an asymmetry in exposure between large and small exchange rate changes is 0.5%. 
in volatility underlying exchange rate exposure (represented by statistically significant GJR term). Only four out of the five firms that show sign asymmetry seem to have evidence for volatility asymmetry as well. Also, only four firms (out of five that show magnitude asymmetry) display evidence for both magnitude asymmetry and asymmetric volatility. Although their exposure to the exchange rate changes are symmetric (represented by statistically insignificant $\beta_3$ and $\beta_4$ terms in mean equation), twenty three firms (or 46%) display evidence for asymmetric volatility associated with exchange rate changes. Only one firm (or 2%) shows all three types of asymmetries. Six firms (or 12%) neither significantly exposed to exchange rate changes nor display asymmetric volatility underlying exchange rate exposure. Table 03 summarises these results which will be discussed in detail below.

Table 03
Statistically significant exposure and asymmetries of exchange rate exposure

<table>
<thead>
<tr>
<th>Number of firms that display:</th>
<th>At 10 % level</th>
<th>At 5 % level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exchange rate exposure</td>
<td>21 (42%)</td>
<td>14 (28%)</td>
</tr>
<tr>
<td>Sign asymmetry</td>
<td>10 (20%)</td>
<td>05 (10%)</td>
</tr>
<tr>
<td>Magnitude asymmetry</td>
<td>09 (18%)</td>
<td>06 (12%)</td>
</tr>
<tr>
<td>Asymmetric volatility</td>
<td>40 (80%)</td>
<td>38 (76%)</td>
</tr>
<tr>
<td>Sign and magnitude asymmetries</td>
<td>01 (02%)</td>
<td>01 (02%)</td>
</tr>
<tr>
<td>Sign and volatility asymmetries</td>
<td>08 (16%)</td>
<td>04 (08%)</td>
</tr>
<tr>
<td>Magnitude and volatility asymmetries</td>
<td>07 (14%)</td>
<td>04 (08%)</td>
</tr>
<tr>
<td>All three asymmetries</td>
<td>01 (02%)</td>
<td>01 (02%)</td>
</tr>
<tr>
<td>Only volatility asymmetry</td>
<td>23 (46%)</td>
<td>23 (46%)</td>
</tr>
<tr>
<td>No asymmetry at all</td>
<td>06 (12%)</td>
<td>06 (12%)</td>
</tr>
</tbody>
</table>

**Sign asymmetry in exchange rate exposure**

We use classification in Koutmos and Martin (2003a) in order to report the sources of sign asymmetry. At 10% level of significance, thirty one firms (or 62%) are not exposed to the exchange rate changes at all. It seems that asymmetric hedging or pricing-to-market with volume constraint are almost not at work in generating sign asymmetry in
exchange rate exposure of the selected sample of Japanese firms. Instead, sign asymmetry seems to stem from either hysteresis or pricing-to-market with market share objective. Nine firms (or 18% of the total sample and 42.86% of the firms that are significantly exposed to exchange rate changes) show sign asymmetry through this source. Nine firms do not show sign asymmetry although their exchange rate exposure is statistically significant. Results also indicate that sixteen out of the nineteen firms that are exposed to exchange rate changes (or 84.21) are net importers. These results are summarised in Table 04.

Table 04
Possible sources of sign asymmetry of exchange rate exposure: empirical evidence

<table>
<thead>
<tr>
<th>$\beta_2 &gt; 0$</th>
<th>$\beta_2 = 0$</th>
<th>$\beta_2 &lt; 0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_3 &gt; 0$</td>
<td>Net exporters</td>
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</tr>
<tr>
<td></td>
<td>Pricing-to-market with market share objective</td>
<td>Pricing-to-market with market share objective</td>
</tr>
<tr>
<td></td>
<td>Hysteresis</td>
<td>Hysteresis</td>
</tr>
<tr>
<td></td>
<td>00 firms or 00.00%</td>
<td>03 firms or 06.00%</td>
</tr>
<tr>
<td>$\beta_3 = 0$</td>
<td>Net exporters</td>
<td>Net exporters or importers</td>
</tr>
<tr>
<td></td>
<td>Symmetric exposure</td>
<td>No exposure</td>
</tr>
<tr>
<td></td>
<td>00 firms or 00.00%</td>
<td>31 firms or 62.00%</td>
</tr>
<tr>
<td>$\beta_3 &lt; 0$</td>
<td>Net exporters</td>
<td>Net importers</td>
</tr>
<tr>
<td></td>
<td>Pricing-to-market under volume constraints</td>
<td>Pricing-to-market under volume constraints</td>
</tr>
<tr>
<td></td>
<td>Asymmetric hedging</td>
<td>Asymmetric hedging</td>
</tr>
<tr>
<td></td>
<td>00 firms or 00.00%</td>
<td>01 firms or 02.00%</td>
</tr>
</tbody>
</table>

Format is adopted from Koutmos and Martin (2003a)
Level of significance used here is 10%

Our results show a similarity with the results of Koutmos and Martin (2003a) which report that 63% of the non-US cases are not exposed to exchange rate changes. In their study, 16% of the total number of cases show sign asymmetry while the relevant figure in this study is 20%. They found that 22% cases in the non-US sample are symmetrically exposed to exchange rate changes. Our results show that nine firms (or 18%) are symmetrically exposed to the changes in exchange rate.

In a way, our results are not directly comparable with Koutmos and Martin (2003a) for the reason that their unit of analysis is different from ours – they use country-sector as the unit of analysis.
Magnitude asymmetry in exchange rate exposure

At 10\% level, nine firms (or 18\% of the total sample and 42.86\% of the firms that are exposed to exchange rate changes) show statistically significant magnitude asymmetry. Most importantly, the sign attached to the coefficient $\beta_4$ in all those cases is positive. Since this is the predicted sign, this supports our argument of magnitude asymmetry which states that firms are more exposed to large exchange rate changes than to small changes. These results are consistent with De Iorio and Faff (1999) who report that Australian industries are more exposed to large exchange rate changes. However, our results are somewhat different from Andren (2001) who observes firms which are more exposed to small exchange rate changes as well.

Asymmetric volatility of stock returns underlying exchange rate exposure

GJR term which represents the asymmetry in volatility is significant at least at 5\% level in the case of thirty eight firms (or 76\% of the total sample)\textsuperscript{10}. The same figure at 1\% level significance is twenty nine (or 58\%). Although they do not show statistically significant exchange rate exposure, twenty three firms (or 46\%) show statistically significant asymmetric volatility underlying exchange rate exposure at least at 5\% level. This means that, although the mechanism through which it comes into being is not very clear, the asymmetry in volatility of stock returns underlying exchange rate exposure at firm level is too remarkable to be ignored. Evidence for asymmetry in volatility underlying exchange rate exposure are also reported at country level in Giurda and Tzavalia (2004), Kanas (2000), Maghrebi et al (2004) and Yang (2003).

There are only four cases which report negative coefficient of the GJR term. Interestingly, in all these four cases, coefficient of GJR term is not significant even at 10\% level. Within the sample, statistically significant coefficients of the GJR term (78\%\textsuperscript{10} Although with a smaller sample, somewhat similar results have been reported in Jayasinghe and Premaratne (2004).)
of the total sample) are always positive. Given the fact that both net exporters and importers are included in the sample (see Table 04 above), this implies that explaining the mechanism underlying volatility asymmetry is somewhat difficult.

Validity of the suggested model

Validity of the suggested model which accommodates three asymmetries has been tested against orthogonalized GARCH(1,1)-t model which does not accommodate any asymmetry (i.e. an orthogonalized GARCH(1,1)-t model whose mean equation is represented by \( r_{it} = \beta_0^t + \beta_1 r_{m,t}^n + \beta_2 r_{xt,t} + \epsilon_i \)). The LR test statistic of the suggested model against GARCH(1,1)-t model is significant at least at 5% level in 39 cases (or 78% of the total sample). More interestingly, even at 1% level of significance the relevant figure is 30 (or 60% of the total sample). This means that, in majority of cases, in estimating exchange rate exposure, the suggested model is superior to its orthogonalized GARCH(1,1)-t counterpart which does not take multiple asymmetries into account.

Reliability of exposure coefficients when asymmetries are taken into account

Initially, we used orthogonalized GARCH(1,1)-t model whose mean equation is represented by \( r_{it} = \beta_0^t + \beta_1 r_{m,t}^n + \beta_2 r_{xt,t} + \epsilon_i \) to estimate exposure coefficients. At 5% level of significance, 28 firms (or 56% of the total sample) show statistically significant exchange rate exposure coefficients. One can cast doubt on the reliability/validity of these results when it is considered in the context of a few factors. First, exposure coefficients in this study are estimated using a trade-weighted exchange rate. At firm level, the use of trade-weighted exchange rates must underestimate the exposure as the firm in question may not be exposed at all to some of the currencies in the basket. Second, given the availability of variety of financial and real hedging activities, it is somewhat difficult to believe that firms are exposed to exchange rate changes to such a large degree. Third, the entire sample in this study consists of large firms. Since they can afford the cost of large-scale real and financial hedging, usually, large firms are assumed
to be heavily engaged in hedging activities which may avoid the exposure to a larger extent.

However, more interestingly, when three types of asymmetries are taken into account with the suggested model represented by equations (3) to (6), the number of firms that has been exposed to exchange rate changes at the same significance level has decreased to 50% of its initial value. Exposure coefficient of seventeen firms became insignificant when asymmetries were taken into account and the significance of the coefficients of only eleven firms remained unchanged. Coefficient of three firms whose exposure was insignificant earlier then became significant as the asymmetries were taken into account. These moderate evidence for the presence of exchange rate exposure is consistent with the three factors mentioned in the previous paragraph. Probably, when the asymmetries in returns and volatility of returns were not taken into account in estimating exposure coefficients, it might have overestimated the exchange rate exposure of firms. The suggested model is able to generate more reliable and consistent estimates as it takes two more stylized facts into account in addition to time varying volatility and fat tails of error term distributions, namely, asymmetries in exchange rate exposure of stock returns and asymmetry in volatility of stock returns underlying the exposure process.

VII Concluding remarks and implications for exposure management and policy implementation

This study cites evidence for the presence of multiple asymmetries in exchange rate exposure. The evidence for sign and magnitude asymmetries of exchange rate exposure are somewhat moderate. 35.14% and 42.86% of the total number of firms that are exposed to exchange rate changes display sign and magnitude asymmetries respectively. Within the given sample, cases that nest both sign and magnitude asymmetries are very rare and only 2% of the total sample show both these asymmetries at the same time. However, we observe strong evidence for the presence of asymmetric volatility of stock
returns underlying exposure process. Asymmetry in volatility of stock returns is present in the case of 76% of the total number of firms in the sample.

In addition to producing evidence for the presence of asymmetries in exchange rate exposure of stock returns and volatility of stock returns underlying exposure process, this study also suggests a model that is able to generate more reliable and consistent estimates. In terms of LR test results, the suggested model seems to be superior to its orthogonalized GARCH(1,1)-t counterparts which do not take asymmetries involved in the exposure process into account.

Most importantly, we observed that significance of exposure coefficients deteriorates drastically when asymmetries are taken into account. One possible interpretation is that the negligence of multiple asymmetries may overestimate exchange rate exposure. The facts that there exists multiple asymmetries in exchange rate exposure and the negligence of those asymmetries in estimating exchange rate exposure may result in unrealistic exposure coefficients have direct implications for exchange rate exposure management and government policy implementation towards financial markets. A few facts in this regard are worth mentioning here. First, it would be important for the firms to know whether the risk profile of their profits related to exchange rate changes is asymmetric as they can then choose the most appropriate hedging instruments for them. For instance, as Ware and Winter (1988) point out, if the risk profile is asymmetric, firms are better off with hedging instruments like Currency Options which also possess asymmetric risk profiles than Forwards or Futures which are more or less suitable for symmetric risk profiles. Second, since the knowledge of the underlying risk profile of an asset in which they are going to invest is one essential part of their armoury, strong evidence of asymmetric exposure of stock returns to exchange rate changes may make individual investors and portfolio managers rethink and readjust their strategies accordingly. For instance, if they happen to invest in the stocks of a large exporter with market share objective, they have to take into account the fact that the stock returns are more sensitive to local currency appreciation than depreciation. Third, evidence for the presence of multiple asymmetries may also motivate financial engineers to come up with new
financial instruments needed for hedging under asymmetric conditions. Third, the
government has to take these asymmetries into consideration when making and
implementing policies. For instance, the government can put more efforts into upgrading
the market for Currency Options and conducting smooth functioning in it. Finally, all
these parties have to understand the complexity stems from the relationship between the
asymmetry in exchange rate exposure and hedging. Asymmetry in the exchange rate
exposure of firms’ profits may force the firms to adopt hedging strategies which in turn
results in asymmetries in exchange rate exposure of stock returns.

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