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Effect of Exchange Rate Exposure on Stock Market: Evidence from Iran

[1]*Reza Ahmadi,* [1]*Mehdi Rezayi and* [2]*Mehrzad Zakeri*

[1]Faculty Member of Rahedanesh Institute of Higher Education, Babol, Iran
[2]Chief of Statistics and Planning, Sina Bank, Iran

Abstract: Modeling exchange rate exposure has been an important growing area of research in the last decade. Changes in exchange rates may also influence the future activities of the firm. And, it is not operationally easy to obtain a significant amount of firm-specific information, especially when the study is focused on a large number of firms. The purpose of present study is a survey on the effect of exchange rate volatility on stocks return in different industries of listed companies in Tehran Stock Exchange using GJR-GARCH model. The data were collected monthly including seven fields of industries: Automotive, metals, machinery, cement, pharmacy, food and chemistry over 1384-1389. We find strong evidence of exchange rate exposure in all three aspects. This implies that the entire currency risk actually faced by firms is not fully captured by the traditional "exchange rate exposure coefficient" alone.

Key words: Exchange rate exposure · GJR-GARCH · Stocks return

INTRODUCTION

A majority of studies in exchange rate exposure[1] 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. [1, 2] 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, [2]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, [3] 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. [4] cite evidence in support of the exchange rate asymmetry between small and large exchange rate changes. However, they report mixed results. [5] who looks into both sign and magnitude asymmetries[2] 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. [6], 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.

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, [2,4,5,7] show evidence of asymmetric exchange rate exposure alone, another set of studies like [1,8,9] considers asymmetry in volatility of stock returns only.

[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.

Corresponding Author: Reza Ahmadi, Faculty Member of Rahedanesh Institute of Higher Education, Babol, Iran

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, [1,8,9] analyze 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.

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 behavior 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 behavior 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 [10-12]. 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.

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 [13] 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 firm plays more than one of the above roles, again the effect may be unclear. On the other hand, as elaborated in [14], 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 effect[6]. This makes one's task of judging the underlying mechanism more difficult.

Interestingly, as [15] 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". [1,8,9] 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.

Data and Preliminary Analysis: Our datasets comprise the daily industrial indexes of seven sectors in Iran which are possibly exposed to exchange rate changes. They include: automotive (Car), chemicals (Chem), machinery (Mach), pharmaceuticals (Drug), cement (Ceme), basic metals (Metal), food industry (Food).

The exchange rate is expressed as local currency price of foreign currency. An increase (decrease) in the index indicates appreciation (depreciation) of the Dollar. Following most of the previous studies, we use nominal exchange rates in this paper[3].

The daily returns (as a percentage) of various industrial sectors (i) and nominal exchange rate (x) on a continuously compounding basis are computed as follows:

$$r_{v,t} = \ln\left(R_{v,t} / R_{v,t-1} \right) * 100 \qquad v = i,\ x,\ m \qquad (1)$$

where $R_{v,t}$ and $R_{v,\ t\text{-}1}$ are the closing values for the trading days t and t-1, respectively.

During the 6-year period of study, the Dollar appreciated by 14.5% on average. Table 1 also displays the summary statistics of returns from industrial sectors. The highest daily return is in Car, averaging 0.033%. The lowest daily returns are in Chem, with negative averages at 0.23%. The standard deviations for returns from these industrial sectors range from 1.92% (Drug) to 1.27% (ceme).

We now turn to various test statistics for the preliminary returns series. As evidenced by the augmented Dickey-Fuller test, returns of all 7 industrial sectors and changes in exchange rate are stationary at the 1% level of significance. However, the Jarque-Bera test for non-normality is highly significant in all seven sectors, thereby rejecting the null hypothesis that the daily returns in the industrial sectors are normally distributed.

The GJR-GARCH Model: The GARCH model pioneered by [16] and its subsequent extension are well-documented in the literature on modeling conditional volatility in empirical economics and finance. One stylized fact is that asset returns are found to exhibit strong asymmetric conditional volatility, thereby indicating that negative return shocks induce greater future volatilities compared with positive shocks of the same magnitude. As such, many variants of GARCH-type models that are capable of capturing volatility asymmetry have been developed. A widely accepted variant of such models that allows for asymmetric effects is the GJR-GARCH model of [17]. In this paper, we adopt a bivariate GJR-GARCH(1,1) model to capture the three aspects of exchange rate exposure of sectoral returns. The mean and variance structures are specified as follows:

Mean equation for sectoral returns:

$$r_{i,t} = a_0 + a_{x\text{-}1} r_{x,t\text{-}1} + \sum_{k=1}^{q} a_{i\text{-}k}\, r_{i,t\text{-}k} + \varepsilon_{i,t} \quad i = 1,2,\ldots,n \qquad (2)$$

Mean equation for changes in exchange rate:

$$r_{x,t} = b_0 + \sum_{l=1}^{s} b_{x,t\text{-}1}\, r_{x,t\text{-}1} + \varepsilon_{x,} \qquad (3)$$

Variance equations:

$$\varepsilon_t = zt\, H_t^{\frac{1}{2}} \quad \varepsilon t|I_{t\text{-}1} = (\varepsilon_{i,t}\ \varepsilon_{x,t})' I_{t\text{-}1} \sim N\,(0, H_t) \ (4)$$

$$h_{i,t} = \omega_i + \alpha_i \varepsilon^2_{i,t-1} + \gamma_i\, d_{i,t\text{-}1} \varepsilon^2_{i,t-1} + \beta_i\, h_{i,t\text{-}1} + \alpha_{ix} \varepsilon^2_{x,t-1} + \gamma_{ix}\, d_{x,t\text{-}1}\, \varepsilon^2_{x,t-1} \qquad (5)$$

$$h_{x,t} = \omega_x + \alpha_x \varepsilon^2_{x,t-1} + \gamma_x\, d_{x,t\text{-}1}\, \varepsilon^2_{x,t-1} + \beta_x\, h_{x,t\text{-}1} \ (\qquad 6)$$

$$h_{ix,t} = \rho_{ix} \quad (h_{i,t} h_{x,t})^{\frac{1}{2}} \qquad (7)$$

Table 1: Preliminary statistics of sectoral returns, market returns and the exchange rate changes

Sector	Car	metal	mach	Drug	ceme	Chem	food	Ex.rate
Mean	0.0332	-0.0045	-0.0433	0.0276	0.0297	-0.2301	0.0106	2.9556
Maximum	9.4684	8.4260	9.6242	12.3268	7.1390	6.7256	6.3298	4.6134
Minimum	-8.3680	-5.4607	-6.4895	-6.1448	-5.3572	-6.4734	-7.1787	1.1994
S D	1.4232	1.5198	1.3144	1.9204	1.2785	1.3241	1.4296	1.4370
Skewness	0.143	0.1545	0.5163	0.3979	0.0250	0.0524	-0.127	-0.0958
Kurtosis	7.9657	7.8230	9.6346	7.5645	6.9163	7.2023	7.7550	1.3038
Jarque-Bera stat	1569.39	1479.69	3348.97	1317.48	803.86	877.79	1527.51	728.4
Runs Test	0.26	-2.49	5.12	3.24	-4.34	-4.23	-4.89	-1.53
ADF stat(4)	-42.87	-46.05	-43.90	-46.61	-43.14	-44.72	-41.28	-47.80

[3]There are at least two reasons to justify the use of nominal rates. First, the use of real exchange rates implies that participants in financial markets instantaneously observe the inflation rates that are needed to obtain the real exchange rate. Second, it is well established that there exists a high correlation between the changes in nominal and real exchange rates [13].

where $r_{i,t}$ is the daily return of industrial sector i at time t and $r_{x,t}$ is the change in exchange rates at time t. In addition, ε_t is a 2 x 1 vector of the daily shocks of $\varepsilon_{i,t}\, \varepsilon_{x,t}$ at time t pair-wise with each sector. And $\varepsilon_t \mid I_{t-1}$ denotes the 2 x 1 vector of random shocks at time t given all available information at time (t-1). We assume that it follows a bivariate normal distribution with 0 mean and variance given by H_t, which is a 2 x 2 variance-covariance matrix. For each sector, the main-diagonal elements of H_t are the conditional variance of sectoral returns and changes in exchange rate captured by the GJR-GARCH (1,1) models in equations (5)-(6), respectively. Here, $_{du,t-1}$ = 1 if $\varepsilon_{u,t-1} <$ 0 and zero otherwise, for $u = i, x$. The off-diagonal element of H_t is the conditional covariance of sectoral returns and changes in exchange rate. Finally z_t denote the standardized errors which are assumed to be independently and identically distributed with mean 0 and variance 1.

Some discussions on the model setup are in order. As regards the mean equation (2) for sectoral returns, we follow Bartov and Bodnar (1994) and others to include lagged variables of exchange rate changes to capture the possible impact on stock returns[4]. As such, the exposure coefficient a_{x-1} measures the sensitivity of sectoral returns at time t to the exchange rate changes at time (t-1). Given that the exchange rate is expressed as local currency price of foreign currency, a positive coefficient implies that sectoral returns increase with a depreciation of exchange rate. This should be the case for those industrial sectors dominated by exporting firms.

Turning to the mean equation in (3) for changes in exchange rate, we assume that it follows an autoregressive process of order s. However, sectoral returns are not included as explanatory variables in this equation. There are two main reasons. First, each industrial sector is sufficiently small as compared to the whole economy. It is therefore reasonably safe to assume that the exchange rates are almost entirely dependent on activities in the rest of the economy (see Bodner and Gentry (1993)). Hence, returns on a particular sector are assumed to have negligible effect on the exchange rate. Second, we have performed the Granger-causality tests for all sectors with changes in exchange rates and we find that none of the returns series Granger-causes exchange rate changes. Similarly, returns of the market portfolio are not included in the mean equation either. Although the "stock-oriented approach" to determining exchange rates provides some theoretical support for such an inclusion, we exclude the market returns because they do not Granger-cause exchange rate changes.

The variance equation in (5) for returns of the i_{th} sector includes the GARCH(1, 1) terms (α_i and β_i) and the GJR term with coefficient γ_i. In order to measure the exchange rate exposure of the volatility of sectoral returns, a cross ARCH term is Included and its impact on volatility of returns is captured by parameter α_{ix}. In other words, a positive and significant estimate indicates that volatility of changes inexchange rates may increase the volatility of sectoral returns. Moreover, a cross GJR term is added to capture the possibly asymmetric volatility of exchange rate changes by parameter γ_{ix}. A negative and significant coefficient implies that a depreciation shock induces even greater volatility in sectoral returns than an appreciation shock of the same magnitude.

Similarly, the variance equation in (6) for changes of exchange rate is assumed to follow a GARCH(1,1) process, together with an GJR term to capture the possibly asymmetric exchange rate volatility by parameter γ_x. The justification is that exchange rate changes are often negatively skewed. See the summary statistics reported in Table 1 of Section 2. As such, we will find some support for asymmetric volatility associated with exchange rate changes provided that the estimated values of γ_x are statistically significant.

The conditional covariance of sectoral returns and exchange rate changes equation in (7) is written as the product of time-invariant correlation coefficient (ρ_{ix}) and square root of the conditional variance of returns and exchange rate changes. The constancy of ρ_{ix} is proposed by Bollerslev (1990) to ensure that the variance and covariance matrix is positive definite.

RESULTS AND DISCUSSIONS

In this section, we will first report and discuss estimation results of the bivariate GJR-GARCH model. This includes all three aspects of exchange rate exposure of sectoral returns and diagnostic checks for adequacy of the proposed model. Then we move on to examine some

[4]We are grateful to one referee for pointing out that the suggested bivariate GJR-GARCH model no longer captures the contemporaneous exchange rate changes in the mean equation. This is due to the time series structures in the reduced form. While the conventional augmented market model is able to capture the contemporaneous exchange rate changes in the mean equation, however, it does not capture the other aspects of exchange rate exposure of sectoral returns as specified in the variance equation discussed in this paper. Apparently, there is a trade off here.

Table 2: Exchange rate exposure of sectoral returns and volatilities in Iran: maximum likelihood estimates

Parameter	Car	metal	Mach	drug	ceme	Chem.	Food
1. a_{x-1}	0.1926***(7.13)	-0.0223(-1.47)	-0.0412**(-2.40)	-0.0124(-0.38)	0.1526***(7.87)	0.0361(1.39)	0.1362***(6.91)
2. b_{x-1}	0.0702**(2.34)	0.0679**(2.56)	0.0646**(2.44)	0.0701***(2.58)	0.0712***(2.66)	0.0687**(2.48)	0.0702***(2.64)
3. ω_i	0.0082***(2.70)	0.0026(1.54)	0.0054**(2.57)	0.0212(1.18)	0.0066**(2.43)	0.0032**(1.99)	0.0023(1.49)
4. β_i	0.8638***(47.35)	0.9155***(54.13)	0.8498***(49.59)	0.9247***(89.23)	0.8834***(43.94)	0.8994***(55.26)	0.8732***(97.97)
5. α_i	0.0884***(5.62)	0.0692***(3.87)	0.1380***(7.34)	0.0603***(4.56)	0.1213***(5.15)	0.0683***(4.32)	0.0918***(6.66)
6. γ_i	0.0409(1.62)	0.0539***(2.92)	0.0570**(2.12)	0.0371*(1.48)	-0.0047(-0.20)	0.0653***(2.92)	-0.0257(-1.09)
7. α_{ix}	0.0488**(2.50)	0.0057(1.01)	0.0152*(1.80)	0.1450***(4.17)	0.0175**(2.43)	0.0210***(2.89)	0.0154**(2.46)
8. γ_{ix}	-0.0331(-1.43)	-0.0032(-0.47)	-0.0191*(-1.75)	-0.1808***(-4.39)	-0.0185**(-2.18)	-0.0218***(-2.81)	-0.0207**(-2.46)
9. γ_x	0.0616***(2.76)	0.0623***(3.11)	0.0518***(3.06)	0.0493***(2.96)	0.0522***(2.93)	0.0483***(3.14)	0.0477***(3.07)
10. ρ_{ix}	0.0593***(2.93)	-0.0376*(-1.69)	-0.0452**(-2.04)	-0.0210(-0.90)	0.0897***(4.34)	0.0162(0.75)	0.0422**(2.00)

dynamic properties of exchange rate exposure of sectoral returns and their conditional volatilities through simulation. The simulated impulse responses of nine sectors will be discussed accordingly. We also demonstrate by simulation that a possible indirect effect of the volatility of exchange rate exposure on sectoral returns could still be possible even if such returns are not directly exposed to changes of the exchange rate in the mean equation.

Tables 2 reports the maximum likelihood estimation of parameters of the bivariate GJR-GARCH model for returns of the 7 industrial sectors. four sectors are significantly exposed to exchange rate change (see row 1 of Tables 2). They include: Car, Ceme, Food and Mach. The estimates of a_{x-1} (exposure coefficient) across these sectors range from-0.0412 (*t*-statistic:-2.4) in Mach to 0.1926 (*t*-statistic: 6.45) in Car. And three of such estimates are greater than 0.1, indicating that returns in these sectors are relatively more sensitive to changes in exchange rate.

In addition, there is support for asymmetric volatility in the GJR-GARCHmodel, as evidenced by the estimated coefficient of own GJR term (γ_i) for three sectors (see row 6 in Tables 2). They include: Mach, Metal and Chem. All three estimates are at least significant at the 5% level and bear the expected positive sign, suggesting that the leverage effect is at work when there is a reduction in sectoral returns. We also find evidence of asymmetric volatility associated with exchange rate changes. Indeed, all the estimated values of γ_x are significant at the 1% level in the variance equation. See row 9 in Tables 2.

Moreover, there are evidence of cross-volatility spillover (α_{ix}) betweenexchange rate changes and sectoral returns in five industrial sectors. They include: Drug, Ceme, chem., Food and Car. See row 7 in Tables 2. The estimates of α ix range from 0.0154 (t-statistic: 2.46) in Food to 0.1450 (t-statistic: 4.17) in Drug. In addition, the sign of α ix is positive in all significant cases, suggesting that an increase in the volatility in foreign exchange market may spillover as an increase in the volatility of sectoral returns.

Furthermore, we find evidence of asymmetric cross-volatility spillover between exchange rate exposure and sectoral returns in four sectors (see row 8 in Tables 2). They are:.Drug, Ceme, Chem and Food. signs of the estimates of the cross GJR term (γ_{ix}) are all negative in all significant cases, ranging from-0.1808 (t-statistic:-4.39) in Drug to-0.0185 (*t*-statistic:-2.18) in Ceme. This implies that the returns in these sectors are not only highly sensitive to the volatility in foreign exchange market but also highly vulnerable to depreciation of exchange rate. Given that the exchange rate is expressed as local currency price of foreign currency and that an increase in the exchange rate indicates depreciation, depreciation shocks in the exchange rate tend to spark off higher fluctuations in the sectoral returns than appreciation shocks. One explanation is that the depreciation of local currency is always regarded as 'bad' news, regardless of the magnitude, thereby signaling the imminent arrival of larger and persistent depreciations.

We next discuss estimates of the constant correlation coefficient (ρ_{ix}) in the bivariate GJR-GARCH model. As can be observed from row 10 of Tables 2, four sectors show statistically significant contemporaneous relationship of the volatility of sectoral returns with that of exchange rate changes at the 5% level. These 4 sectors include: Car, Mach, Ceme and Food. We note in passing that our estimates of sectoral correlation coefficients are relatively smaller in magnitude as compared to those based on national stock index returns.

Table 3 summarizes findings of various aspects of exchange rate exposure that are significant at the 5% level for each sector. They include: exposure in returns(a_{x-1}), exposure in volatility (α_{ix}), asymmetric exposure in volatility (γ_{ix}), and correlation between exchange rate changes and sectoral returns (ρ_{ix}), respectively.

Table 3: Exchange rate exposure of sectoral returns and volatilities in Iran: a summary

Sector	Exposure in returns ----------- a_{x-1} -----------	Correlation --------- ρ_{ix} ---------	Exposure in volatility --------- α_{ix} ---------------	Asymmetric exposure in volatility ------------------ γ_{ix} ------------------
Car	√	√	√	-
Metal	-	-	-	√
Mach	√	√	-	√
Drug	-	-	√	-
Ceme	√	√	√	-
Chem.	-	-	√	√
Food	√	√	√	-

Table 4. Exchange rate exposure of market returns in Iran

Component	Parameter	Estimate
Exposure: returns Exposure	a_{x-1}	0523/0 (93/0)
variance Asymmetric variance	α_{mx}	0389/0 (09/1)
exposure	γ_{mx}	0105/0 (18/0)
Correlation	ρ_{mx}	0042/0- (21/0-)

Table 4 shows the diagnostics including the summary statistics of the standardized residuals. This implies that the proposed bivariate GJR-GARCH model is adequate for capturing the three aspects of exchange rate exposure of sectoral returns.

Concluding Remarks: We have employed a bivariate GJR-GARCH model to capture the exchange rate exposure of seven Iranian industrial sectors, with emphasis on three aspects of exchange rate exposure: sensitivity of sectoral returns to changes in exchange rate; sensitivity of the conditional volatility of sectoral returns to that of changes in the exchange rate and its possibly asymmetric effect; and the correlation between sectoral returns and exchange rate changes. In general, we find strong evidence of exchange rate exposure in all three aspects. This implies that the entire currency risk actually faced by firms is not fully captured by the traditional "exchange rate exposure coefficient" alone.

The results indicate that there is a positive significant relationship between stock return and the previous stock return and also there is a positive significant relationship with asymmetric effect of exchange volatility in cement and food industries. Also there is a negative significant relationship between exchange return and asymmetric effect of exchange volatility in pharmacy and chemistry industries. Furthermore there is a positive significant relationship between stock return and the previous stock return and exchange volatility in automotive industry. Ultimately there is a negative significant relationship between stock return in machinery industry with stock return of the previous period, but there is no any significant relationship between stock return and studying variables in metal industry.

The simulation exercise reveals some interesting patterns of the dynamics of exchange rate exposure of sectoral returns. First, the impact of an exchange rate shock on returns, though large in magnitude, may die down relatively quickly. Second, even if the returns are not directly exposed to the exchange rate changes, as long as they are sensitive to its own volatility, there could be a persistent indirect impact via the exposure of conditional volatility of the returns to the volatility in foreign exchange markets. Finally, if the volatility of sectoral returns is significantly exposed to the volatility of changes in exchange rate with sufficiently large magnitude, the impact of an exchange rate shock on the conditional volatility of the returns may be even higher than the impact on its own volatility.

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