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Asymmetric International Transmission in the Conditional Mean and Volatility to the Japanese Market from the U.S.: EGARCH vs. SV Models

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Asymmetric International Transmission in the Conditional Mean and Volatility to the Japanese Market from the U.S.:EGARCH vs. SV Models

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June, 2007 (revised)

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Abstract:

This paper investigates whether the upturns and downturns of the U.S. market exert asymmetric influence on the conditional mean and volatility of the Japanese market using the daily returns on stock price indices. Using both the EGARCH and SV models, which simultaneously allow two kinds of asymmetric international transmissions across the markets, the result reconfirms the symmetric transmission in the conditional mean obtained by Bahng and Shin (2003) and the asymmetric transmission in the conditional volatility obtained by Koutmos and Booth (1995) although each of them analyzed the only one spillover effect separately. Although the EGARCH and SV models lead to similar results about the spillover effects, the SV model is preferred to the EGARCH model in terms of the Lagrange Multiplier test of the EGARCH against the SV models. The shock to volatility in the U.S. market with the SV model is asymmetrically transmitted to the volatility in the Japanese market.

Keywords: asymmetric transmission; conditional mean and volatility; Japan and the U.S. stock markets; EGARCH and SV models;
JEL Classification Number: G14; G15

1. Introduction

This paper studies asymmetric transmissions of return and volatility in the stock price index of the U.S. stock market into the Japanese stock market. Numerous researchers found significant contemporaneous return correlations. In addition, dynamic market interdependences which indicate causal relationships were also investigated by many researchers who report significant price volatility spillovers between advanced markets. (Hamao et al (1990), Bae and Karolyi (1994), Karolyi (1995) and Karolyi and Stulz (1996), Ng (2000), Miyakoshi (2003), Kim (2005) among others). Furthermore, some researchers considered asymmetric international transmission effects. By simply using a vector autoregressive (VAR) framework, Pagan and Soydemir (2001) and Bahng and Shin (2003) found that the returns of the domestic market were more sensitive to downturns than uptowns in the foreign markets. Using the ARCH-type models, Booth, Martikainen and Tse (1997), and Koutmos and Booth (1995) investigated the asymmetric international transmission of volatility amongst the Scandinavian stock markets and the Japanese, UK, and US markets, respectively. However, there is no research simultaneously dealing with both asymmetric international transmissions in return and volatility.[1]

Most analyses of international transmission in return and volatility of the market of a country to the other country are conducted using the framework of the ARCH type models, and there is no research on the international spillover using the stochastic volatility (SV) models. The SV model is intuitively appealing since it allows the contemporaneous shock to the present volatility, unlike the ARCH-type models (Taylor (1994) and Andersen (1994)). In addition, the SV model includes the EGARCH model as a limiting case when the standard deviation of shocks on volatility goes to zero. Kobayashi and Shi (2005) proposed a method for testing the hypothesis of the EGARCH against the SV model. More importantly, the SV model is able to analyze whether the shock to the volatilities in the foreign market is transmitted into the volatilities in the domestic market, whilst the EGARCH model is not. Nevertheless, the SV model is not frequently used for the empirical analyses of financial markets[2].

The purpose of this paper is to investigate whether the upturns and downturns of

[1] Koutmos (1998), Nam et al. (2003) and many others found that the returns and volatility react more to the previous downturns of their own market than to the previous upturns. But, they did not investigate the asymmetric international transmissions in return and volatility.

[2] Although it had been computationally difficult to estimate the SV model, estimation of the SV model is no more burdensome as before since various efficient methods of estimation have been extensively developed in recent years. Shimada and Tsukuda (2005) proposed a new estimation method. See Broto and Ruiz (2004) for reviewing estimation methods.

the U.S. market exert an asymmetric influence on the conditional mean and volatility of the Japanese market using the daily returns on stock price indices. We use both the EGARCH and SV models, which allow the simultaneous treatment of two kinds of asymmetric international transmissions in the conditional mean and volatility across the market. First, we examine whether the previous return on the US markets affects the present return on the Japanese market, and whether the magnitudes of effects are the same for both positive and negative returns. Second, we investigate whether the previous negative shock (bad news) on the return in the US market differently affects the present volatility in the Japanese market from when the previous positive shock (good news) on the return in the US market does. We also examine the performance of the EGARCH model and the SV model using the method of Kobayashi and Shi (2005).

The empirical results reveal that (i) the returns in the Japanese market react symmetrically to the previous upturns and downturns of the U.S. market, (ii) the previous negative shock (bad news) in the U.S. market increases current volatility in the Japanese market, while the previous positive shock (good news) in the U.S. market does not significantly increase current volatility in the Japanese market (asymmetric transmission in the conditional volatility). Our simultaneous treatment reconfirms the symmetric transmission in the conditional mean obtained by Bahng and Shin (2003) and the asymmetric transmission in the conditional variance obtained by by Koutmos and Booth (1995), whilst each of them analyzed the only one spillover effect separately. Although the SV analysis leads to results that are similar to those of the EGARCH analysis, the SV model is preferred to the EGARCH model based on the hypothesis testing. Moreover, the shock to the volatility in the U.S. market is asymmetrically transmitted to the volatility in the Japanese market. However, the EGARCH model cannot describe this kind of shock to the volatility. Thus, the SV model incorporating such features of the U.S. market is useful for analyzing the Japanese stock market.

The organization of the paper is as follows. Section 2 explains the EGARCH model with spillover effects and discusses the estimation results of asymmetric transmission effects on the conditional means and variances. Section 3 employs the SV model with international transmission effects, tests the EGARCH against the SV, and compares the results with those by the EGARCH model. Section 4 gives some concluding remarks.

2. Data and the EGARCH model analysis

2.1 Data and summary statistics

We use the daily closing prices of TOPIX for the Japanese market and the S&P 500 for the U.S. market; both are measured in local currency over a twelve-year period beginning from January 1, 1993 to December 31, 2004. The number of observations is 2861.[3] The stock price indices and returns for the whole period are illustrated in Figure 1. Both the stock price indices and returns exhibit large fluctuations over the period. However, the reason for the changes of movement in the price indices and returns is not apparent from Figure 1.

Table 1 indicates the number of observations, mean, standard deviation, skewness, excess kurtosis, the first order autocorrelation for the returns, and the first order autocorrelation for the squared returns of each country. The asterisks in columns 4–7 denote that the values are significant from zero at the 5% level. The typical features of stock returns, such as fat tail, spiked peak, and the persistence of variance are observed in both the Japanese and U.S. stock markets. The first order autocorrelation of the returns is significant for the Japanese markets but not for the U.S. markets at the 5% level. Therefore, the ARCH-type model incorporating the above facts is appropriate for analyzing the return series.

[Insert Figure 1 and Table 1]

2.2 The EGARCH model with asymmetric international transmission

We first provide the nested EGARCH model to examine the asymmetric international transmission in returns and volatilities. The stock return on the Japanese stock market is assumed to have a first-order autoregressive (AR) model with possibly asymmetric effects of the lagged variable.

$$R_{JP,t} = a_0 + a_1 R^{+}_{JP,t-1} + a_2 R^{-}_{JP,t-1} + b_1 R^{+}_{US,t-1} + b_2 R^{-}_{US,t-1} + \varepsilon_{JP,t}, \qquad (1)$$

where $R^{+}_{JP,t-1} = \max\{R_{JP,t-1}, 0\}$, and $R^{-}_{JP,t-1} = \min\{R_{JP,t-1}, 0\}$. The disturbance term has heteroscedasticity,

$$\varepsilon_{JP,t} = \sigma_{JP,t}\, z_t, \qquad z_t \sim \text{i.i.d. } N(0,1). \qquad (2)$$

[3] If either the TOPIX or S&P 500 is not open on a particular day, we have excluded the data for that day from the observation. Hence, the two markets have the same number of observations. The URL of TOPIX historical prices is http://table.yahoo.co.jp/t?s=998405.t&g=d and of S&P 500 historical prices is http://finance.yahoo.com/q/hp?s=%5EGSPC.

The EGARCH model proposed by Nelson (1991) specifies the log-volatility process as

$$\ln \sigma^2_{JP,t} = \phi_0 + \phi_1 \ln \sigma^2_{JP,t-1} + \phi_2 z^+_{JP,t-1} + \phi_3 z^-_{JP,t-1} + \delta_1 z^+_{US,t-1} + \delta_2 z^-_{US,t-1} \quad (3)$$

where $z^+_{JP,t-1} = \varepsilon^+_{JP,t-1} / \sigma_{JP,t-1}$, $z^-_{JP,t-1} = \varepsilon^-_{JP,t-1} / \sigma_{JP,t-1}$, and $\varepsilon^+_{JP,t-1}(\varepsilon^-_{JP,t-1})$ are similarly defined to $R^+_{JP,t-1}(R^-_{JP,t-1})$. The $R^+_{US,t-1}(R^-_{US,t-1})$ and $\varepsilon^+_{US,t-1}(\varepsilon^-_{US,t-1})$ for the U.S. are defined to the corresponding Japanese ones. The present volatility of the EGARCH model is determined completely by the past observations on the returns. The EGARCH model of (1), (2), and (3) for the Japanese market has a corresponding model for the U.S. market, although we do not explicitly state it here.

We note that $z^+_{JP,t-1}$, $z^-_{JP,t-1}$, $z^+_{US,t-1}$, and $z^-_{US,t-1}$ are treated as the observable shocks. The data for these variables are the residuals calculated from equations (1), (2), and (3) without the international transmission for the Japanese and U.S. stock markets.[4] Thus, this model is not a bivariate EGARCH model consisting of both the Japanese and the U.S. markets.

The return generating processes incorporate either the symmetric or asymmetric transmission of the returns of the previous U.S. market. On the other hand, the log-volatility processes incorporate the symmetric (or asymmetric) transmission of the shocks on the previous returns in the U.S. market ($z^+_{US,t-1}$ and $z^-_{US,t-1}$).

Second, we provide hypotheses to examine whether the asymmetric international transmission exists in the Japanese market. The null hypothesis of the symmetric international transmission can be expressed using (1), (2), and (3):

$$H_1 : b_1 = b_2 \ \ and\ \ \delta_1 = -\delta_2 \quad \text{vs.} \quad H_{1a} : b_1 \neq b_2 \ \ or\ \ \delta_1 \neq -\delta_2 \ ,$$

$$H_2 : b_1 = b_2 \quad \text{vs.} \quad H_{2a} : b_1 \neq b_2 \ ,$$

$$H_3 : \delta_1 = -\delta_2 \quad \text{vs.} \quad H_{3a} : \delta_1 \neq -\delta_2 \ . \quad (4)$$

We note that the null hypothesis H_1 encompasses the hypotheses H_2 and H_3. If we reject the null hypothesis H_1, we must acknowledge the existence of the asymmetric international transmission and use the general model proposed in this paper. Moreover, we must analyze whether the asymmetric transmission of the returns or the volatility

[4] For the Japanese market, these data are the residuals calculated from the equations: $R_{JP,t} = a_0 + a_1 R^+_{JP,t-1} + a_2 R^-_{JP,t-1} + \varepsilon_{JP,t}$, and $\ln \sigma^2_{JP,t} = \phi_0 + \phi_1 \ln \sigma^2_{JP,t-1} + \phi_2 z^+_{JP,t-1} + \phi_3 z^-_{JP,t-1}$.

exists by testing H_2 and H_3. The null hypothesis H_2 was examined by Pagan and Soydemir (2001) and Bahng and Shin (2003) in the model with only asymmetric international transmission in returns. The H_3 was tested by Booth, Martikainen, and Tse (1997) and Koutmos and Booth (1995) in the model with only asymmetric international transmission in volatilities. The intuition behind this comparison between H_2 and H_3 is shown in Figure 2 (a) and (b).

[Insert Figure 2]

2.3 Estimation Results and Testing Hypotheses

We examine the asymmetric international transmission effect on the Japanese markets from the U.S. The estimation result in Table 2 is summarized as follows:

(i) Adjustments within the domestic market. The previous positive return positively affects the present return, but the previous negative return does not. The previous shock in the return equation (1) increases the present volatility in the equation (3), but the effects of negative shock are greater than that of positive shock (leverage effect).

(ii) International Transmission across the markets: The previous positive (negative) return on the U.S. markets positively (negatively) affects the present return on the Japanese market, and the magnitude of the effects is the same for both the positive and negative returns (symmetric transmission in the conditional mean). The previous negative shock (bad news) on the return in the U.S. market increases the present volatility in the Japanese market, whereas the previous positive shock (good news) does not (asymmetric transmission in the conditional variance).

[Insert Table 2]

Our simultaneous treatment of the conditional variance and conditional mean reconfirms the asymmetric transmission in the conditional variance obtained from a separate treatment by Koutmos and Booth (1995), and the symmetric transmission in the conditional mean by Bahng and Shin (2003).

We also reconfirm these results by testing hypotheses H_1, H_2, and H_3. As shown in the first column of Table 3, we can reject the null hypothesis of H_1 even at the 1% level, supporting "asymmetric international transmission in returns and volatilities" in our generalized model. On detailed inspection, we can not reject the null hypothesis of H_1 (symmetric international transmission in returns) at the 10% level, supporting the results by Bahng and Shin (2003). However, we can reject the null hypothesis of H_2

(symmetric international transmission in volatilities) at the 1% level, supporting the results by Koutmos and Booth (1995).

[Insert Table 3]

3. Analysis by the SV model in comparison with the EGARCH model

This section first specifies the SV model and then shows that the SV model is preferable to the EGARCH model for describing the return processes on both the Japanese and U.S. stock price indices based upon the Lagrange Multiplier specification test proposed by Kobayashi and Shi (2005).

3.1 The SV model with international transmission effects

The SV model with international transmission effects is described by

$$\ln \sigma^2_{JP,t} = \phi_0 + \phi_1 \ln \sigma^2_{JP,t-1} + \phi_2 z^+_{JP,t-1} + \phi_3 z^-_{JP,t-1} + \delta_1 z^+_{US,t-1} + \delta_2 z^-_{US,t-1} + \lambda_1 \eta^+_{US,t-1} + \lambda_2 \eta^-_{US,t-1} + \eta_{JP,t}. \tag{5}$$

where $\eta_{JP,t} \sim \text{i.i.d.N}(0, \sigma^2_\eta)$, in addition to (1) and (2). The present volatility of the SV model is not completely determined but depends on the present shocks. The SV model of (1), (2), and (5) for the Japanese market has the corresponding model for the U.S. market.[5] We note that $R^{\pm}_{JP,t-1}$, $R^{\pm}_{US,t-1}$, $z^{\pm}_{JP,t-1}$, $z^{\pm}_{US,t-1}$ and $\eta^{\pm}_{US,t-1}$ in (1) and (5) are treated in an analogous manner to the variables in (1)–(3). Unlike the EGARCH model, the volatilities are unobservable stochastic variables. Therefore, we use the smoothing estimates of $z^{\pm}_{US,t-1}$ and $\eta^{\pm}_{US,t-1}$ as the spillover variable. The equation (5) expresses the transmission effects of the previous volatility shocks in the U.S. ($\eta_{US,t-1}$), which do not appear in the analysis using the EGARCH model.

3.2 The SV vs. EGARCH Models

The SV model reduces to the EGARCH model if $\sigma_\eta = 0$. Kobayashi and Shi (2005) proposed the LM statistic for testing the null of the EGARCH model against the SV model. Their LM test statistic is approximately distributed as N (0, 1) under the null hypothesis (i.e., $\sigma_\eta = 0$).

Table 4 indicates that the null of the EGARCH model against the SV model is

[5] We apply the non-linear maximum likelihood method (MLE) proposed by Watanabe (1999) for estimating the SV models throughout this paper. This method is applicable for many types of SV models. The number of grids for the numerical integration is set to 50 in this paper as recommended by Watanabe (1999).

strongly rejected in both the Japanese and U.S. markets. The result of this paper is conformable to the evidence Kobayashi and Shi (2005) found for the Japanese stock market. The result in this section provides a justification for using the SV model to investigate the spillover effects from the U.S. stock market to the Japanese stock market as an alternative to the EGARCH model. Note that $z^{\pm}_{JP,t-1}$ and $z^{\pm}_{US,t-1}$ in both (3) and (5), and $\eta^{\pm}_{JP,t-1}$ and $\eta^{\pm}_{US,t-1}$ in (5) are the residuals calculated from the equations without international transmission for the Japanese and U.S. stock markets.

[Insert Table 4]

3.3 Estimation Results and Testing Hypotheses

Table 5 presents the estimates of the SV model of (1), (2), and (5). The estimates of these parameters are very close to those in Table 2 except for the estimate of ϕ_2 and ϕ_3. In particular, the estimated value of ϕ_2 is positive and significant in Table 2, while it is negative and significant in Table 5. In other words, the SV model shows that the previous positive shock in the return equation decreases the present volatility, but the previous negative shock in the return equation does not affect the present volatility.

[Insert Table 5]

We can also test the null hypotheses in (4) using the SV model. The log-volatility process in (5) has two sources of transmission from the U.S. to the Japanese market: the first is the standardized shock to the U.S. stock price ($z^{+}_{US,t-1}$, $z^{-}_{US,t-1}$), and the second is the shock to the volatility in the U.S. market ($\eta^{+}_{US,t-1}, \eta^{-}_{US,t-1}$). The second source of transmission effects does not appear in the EGARCH model. The asymmetry through the second source can be tested by the hypothesis

$$H_4 : \lambda_1 = \lambda_2 \ , \quad H_{40} : \lambda_1 \neq \lambda_2 \ . \qquad (6)$$

The second column of Table 3 presents the testing results. Comparing the second column with the first column, we recognize that the result using the SV model is the same as that using the EGARCH model. The null hypothesis of H_4 is not rejected. However, as shown in Table 5, the positive shock $\eta^{+}_{US,t-1}$ on the volatility in the U.S. market is positively transmitted into the volatility in the Japanese market at the 10% level in a one-sided test, while the negative shock $\eta^{-}_{US,t-1}$ is not significantly transmitted. This fact supports the asymmetric transmission. Although this fact is not necessarily conformable with the result of the hypothesis test of H_4, we will perceive a weak evidence for the existence of asymmetric transmission. We generally think that the shock to the volatility transmits into the volatility in the other country, so did a one-sided test and not a both-sided test. The SV model is preferred to the EGARCH model based on the Lagrange Multiplier test of Kobayashi and Shi (2005). The SV analysis leads to the similar results to those of the EGARCH analysis except for one important point, i.e., the shock to the volatility in the U.S. market is asymmetrically transmitted into the volatility in the Japanese market. However, the EGARCH model cannot describe the shock to the volatility.

Hamao et.al (1990) claimed that the daily returns defined by the log-difference between the openning and closing prices are preferred to the close-to-close returns in order to examine the spillover effects between the two markets. We carried out all the calculations in this paper using the open-to-close returns. However, the results are almost the same as those obtained by the close-to-close daily returns, although we do not explicitly report this here.

4. Concluding remarks

This paper investigates whether the upturns and downturns of the U.S. market exert any asymmetric influence on the conditional mean and variance of the Japanese market. We use the EGARCH and SV models, which allow the simultaneous treatment of two kinds of asymmetric transmissions across the markets. Our simultaneous treatment reconfirms: (i) the symmetric transmission in the conditional mean obtained from the separate treatment by Bahng and Shin (2003), (ii) the asymmetric transmission in the conditional volatility obtained by Koutmos and Booth (1995). Although the EGARCH and SV models analyses lead to empirically similar results, the SV model is preferred to the EGARCH model in the sense that the EGARCH model is rejected against the SV model based on the Lagrange Multiplier test by Kobayashi and Shi (2005). Moreover, one important advantage of the SV model over the EGARCH model is that the former is able to incorporate the asymmetric transmission of the shock to the volatility in the U.S. market to the volatility in the Japanese market while the latter is not.

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Table 1. Summary statistics

	NOBS (1)	MEAN (2)	STDEV (3)	SKEW (4)	EXKURT (5)	ρ(1) (6)	ρ2(1) (7)
Japan	2861	−0.007	1.231	0.008	2.368*	0.074*	0.099*
U.S.	2861	0.028	1.069	−0.178*	3.770*	−0.002	0.216*

Note: "NOBS," "STDEV," "SKEW," "EXKURT," "ρ(1)," and "ρ2(1)" denote the number of the observations, standard deviation, skewness, excess kurtosis, the first-order autocorrelation of the return process, and the first-order autocorrelation of the squared return process, respectively. The asterisk (*) represents statistical significance at the 5% level.

Table 2. Estimates of the EGARCH model with asymmetric transmission

a_0	a_1	a_2	b_1	b_2	ϕ_0	ϕ_1	ϕ_2	ϕ_3	δ_1	δ_2
Const	$R_{JP,t-1}^{+}$	$R_{JP,t-1}^{-}$	$R_{US,t-1}^{+}$	$R_{US,t-1}^{-}$	Const	$\ln\sigma^2_{JP,t-1}$	$z_{JP,t-1}^{+}$	$z_{JP,t-1}^{-}$	$z_{US,t-1}^{+}$	$z_{US,t-1}^{-}$
−0.051	0.104*	0.017	0.349*	0.398*	−0.162*	0.964*	0.124*	−0.242*	0.000	−0.069*
(0.032)	(0.031)	(0.035)	(0.033)	(0.035)	(0.018)	(0.006)	(0.017)	(0.018)	(0.021)	(0.019)

Note: Robust standard errors are in parentheses. The asterisk (*) represents statistical significance at the 5% level.

Table 3. Test of Hypotheses: Asymmetric vs. Symmetric transmission

Hypotheses	EGARCH	SV
H1: $b_1 = b_2$ and $\delta_1 = \delta_2$	11.530*	7.155*
	(0.003)	(0.028)
H2: $b_1 = b_2$	0.785	1.365
	(0.376)	(0.243)
H3: $\delta_1 = \delta_2$	11.018*	5.988*
	(0.001)	(0.014)
H4: $\lambda_1 = \lambda_2$		0.705
		(0.240)

Note: The test statistics for H_1 is asymptotically distributed as $\chi^2(2)$, for H_2 and H_3 are asymptotically distributed as $\chi^2(1)$, and for H_4 is asymptotically as N(0, 1) under the null hypothesis. P-values are within parentheses. In particular, the p-value for H_4 is for a one-sided test. The asterisk (*) represents statistical significance at the 5% level.

Table 4. Test for the EGARCH against the SV model, and the log-likelihoods

	LM statistic	Log Likelihood (EGARCH)	Log Likelihood (SV)
Japan	14.43*	−4454.69	−4409.68
U.S.	10.98*	−3799.25	−3769.89

Note: The LM test statistic proposed by Kobayashi and Shi (2005) is asymptotically distributed as N (0, 1) under the null hypothesis of the EGARCH model (i.e., $\sigma_\eta = 0$). The critical value at the 5% level is 1.65. The asterisk (*) represents statistical significance at the 5% level.

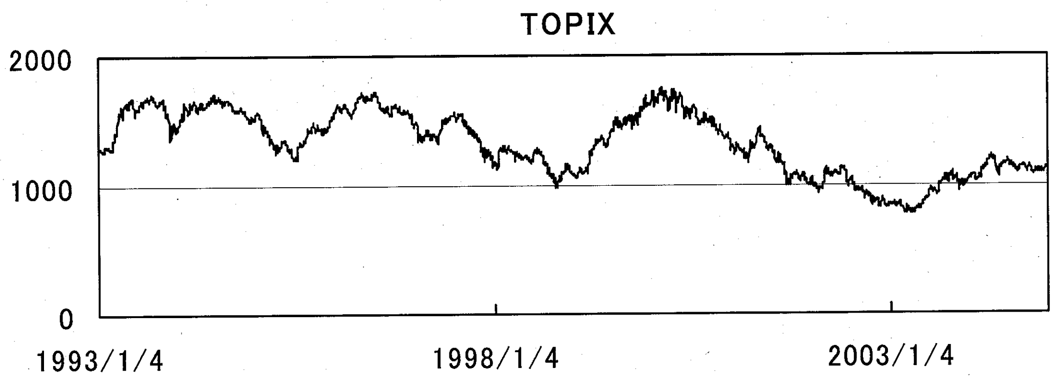
Table 5. Estimates of the SV model with asymmetric transmission

a_0	a_1	a_2	b_1	b_2
Const.	$R_{JP,t-1}^{+}$	$R_{JP,t-1}^{-}$	$R_{U.S.,t-1}^{+}$	$R_{U.S.,t-1}^{-}$
−0.054	0.112*	0.005	0.328*	0.395*
(0.032)	(0.031)	(0.034)	(0.035)	(0.036)

ϕ_0	ϕ_1	ϕ_2	ϕ_3	σ_η	δ_1	δ_2	λ_1	λ_2
Const.	$\ln\sigma_{JP,t-1}^{2}$	$Z_{JP,t-1}^{+}$	$Z_{JP,t-1}^{-}$		$Z_{U.S.,t-1}^{+}$	$Z_{U.S.,t-1}^{-}$	$\eta_{U.S.,t-1}^{+}$	$\eta_{U.S.,t-1}^{-}$
−0.013	0.969*	−0.094*	−0.036	0.157	0.008	−0.075*	0.575$^{\Delta}$	0.097
(0.022)	(0.007)	(0.034)	(0.035)	(0.019)	(0.033)	(0.028)	(0.396)	(0.374)

Notes: Robust standard errors are in parentheses. The asterisk (*) represents statistical significance at the 5% level and Δ represents significance at the 10 % level.

Figure 1. Japanese Stock Prices



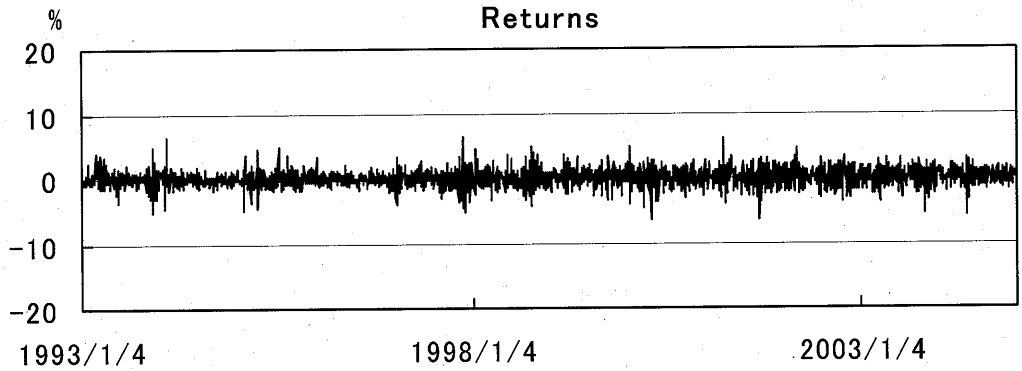
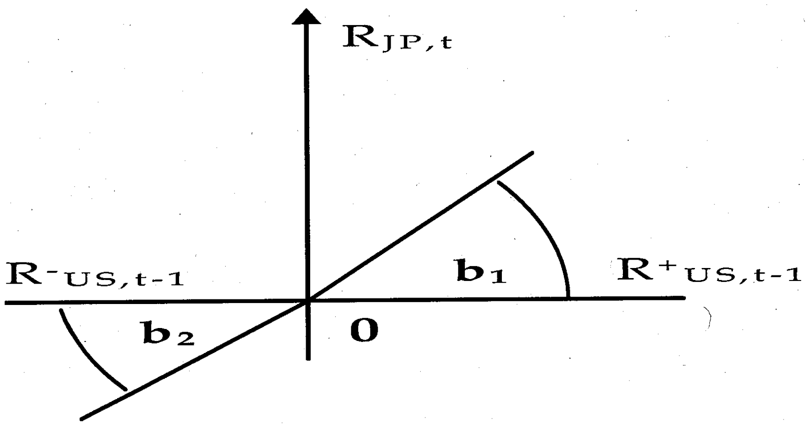
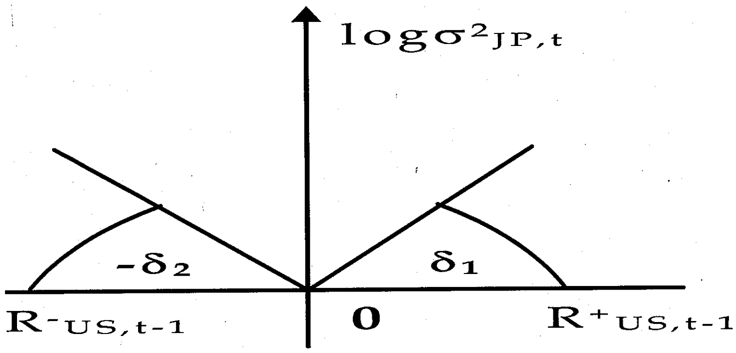


Figure 2. Null Hypotheses for H_2, H_3, and H_4

(a) H_2



(b) H_3



(c) H_4