International Asset Excess Returns and Multivariate Conditional Volatilities

Thomas C. Chiang, Ph.D.*
Marshall M. Austin Professor

Department of Finance
Drexel University
3141 Chestnut Street
Philadelphia, PA 19104, USA
Tel: 215-8951278
Fax: 609-2650141
Email: chiangtc@drexel.edu

Sheng-Yung Yang, Ph.D.
Assistant Professor

Department of Finance
National Chung Hsing University
250 Kuo Kuang Road
Taichung 402, Taiwan ROC
Tel: 886-4-22850940
Fax: 886-4-22856015
Email: shengyang@nchu.edu.tw

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Abstract

This paper constructs a multivariate model in relating multi-asset excess returns to their conditional variances. Applying weekly data to investigate the foreign-exchange risk premium, the evidence from a multivariate GARCH model shows that the foreign-exchange excess returns are significantly correlated with economic fundamentals such as the real interest-rate differential, long-short interest-rate spread differential, and equity-premium differential. The evidence also suggests that foreign-exchange excess returns are not independent of the conditional variances of these fundamental variables, supporting the time-varying risk-premium hypothesis.

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1. Introduction

By definition, an exchange rate is the price of one currency in terms of another and a forward rate is the contractual exchange rate established at date t for a transaction that will occur at date $t+k$ in the future (the maturity date). Assuming that the forward-exchange market is efficient and speculators are rational, risk-neutral investors ensure that the forward rate is an unbiased predictor of the expected future spot rate. However, the unbiasedness hypothesis has been rejected by many empirical studies based on various theoretical arguments, econometric techniques, and data sets (e.g., Hansen and Hodrick, 1980; Fama, 1984; Korajczyk, 1985; Hodrick, 1987; Chiang, 1988; Barnhart and Szakmary, 1991; Goodhart et al., 1997).

Attempts in literature to explain risk premiums in the foreign-exchange market have taken several forms.[1] The first approach is the portfolio-balance model that seeks to explain the risk premium in a mean-variance optimization framework. In this model the risk premium depends in a specific way on the supplies of assets denominated in various currencies, the variance-covariance matrix of the rates of returns, and the coefficient of risk aversion. Research along this line includes Frankel (1982), Frankel and Engel (1984), Lewis (1988), Engel and Rodrigues (1989), Giovannini and Jorion (1989), and Thomas and Wickens (1993). The general results, however, show that the portfolio-balance model based on mean-variance optimization does not perform well in explaining *ex ante* returns.

The second approach is derived from an intertemporal framework that works directly with first-order conditions of the representative agent maximizing his/her expected utility. Due to the difficulty of measuring explanatory variables and other data problems, the exchange-risk premium in empirical studies is usually linked to latent variables or to the conditional variances of exchange rates and/or exogenous variables. By introducing instrumental

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[1] Hodrick (1987) and Engel (1996) contain excellent surveys on these issues and historical references.

variables as proxies for the risk premium, Hansen and Hodrick (1983), Mark (1985), Giovannini and Jorion (1987), and Bekaert and Hodrick (1992) find evidence consistent with the time-varying risk-premium hypothesis. In contrast, Domowitz and Hakkio (1985), Baillie and Bollerslev (1990), Kaminsky and Peruga (1990), and Hu (1997) find weak support for time-varying risk premiums. The estimated results in general are diverse and fail to reach an agreement since estimates of the variations and the justification of the instrumental variables depend heavily on the information set that researchers choose.

The third approach is to employ the Capital Asset Pricing Model (CAPM) to price foreign-exchange risk. Here the risk premium is a linear function of risk, a measure of the covariability between foreign-exchange excess return and stock-market excess return. Roll and Solnik (1977) and Robichek and Eaker (1978) relate the exchange return to systematic risk. Mark (1988) extends the static CAPM to the intertemporal setting by specifying the model in a conditional environment where the systematic risk is parameterized following ARCH modeling strategy. Chiang (1991), Morley and Pentecost (1998), and Jiang and Chiang (2000) find supportive evidence to relate foreign-exchange risk premium to relative *ex ante* risk in national stock markets. This approach assumes that domestic and foreign bond and equity markets are interrelated such that the risk premium identified in one market may be related to the risk or excess return in another. Accordingly, the risk premium in the foreign-exchange market can then be explained by the difference in the expected excess returns in the domestic stock market relative to the foreign stock market.

Given the increasing international financial-market integration and rapid information processing through Internet developments (Giovannini and Jorion, 1987; Eun and Shim, 1989), international-asset excess returns should be modeled in a more general framework. That is, excess returns from foreign-exchange markets should be associated with a vector of variables that dictate international trades and capital flows, including real interest-rate differentials, interest-rate spread differentials, and equity-premium differentials. Moreover, expected excess currency returns in a highly integrated financial market should be viewed as a compensation for risk taking, as reflected in the conditional variances. The latter may include conditional volatilities developing in foreign-exchange market as well as other markets, such as goods, bonds, and stocks. This research is motivated by the market phenomena discussed in above and some recent advances in econometric techniques by Engle (1986) and his associates (Bollerslev, 1986; Baillie and Bollerslev, 1990; Bollerslev and Wooldridge, 1992).

Our study differs from previous studies in several aspects. First, the mean equation includes a vector of excess returns pertinent to explaining the exchange-rate premiums. Second, the conditional variances are modeled in a VAR-GARCH-in-mean process to capture the dynamic aspect of risk. Thus, the dynamic elements for the first and second moments of asset excess returns are incorporated into a unified equation. Third, the sample includes nine major currency prices relative to the US dollar and extends from January 1980 through December 1998 in order to document the recent experience of floating exchange rates. Finally, as noted by Baillie and Bollerslev (1990), it is important to employ high-frequency data to detect relatively short-lived risk premiums or market inefficiencies (Hansen and Hodrick, 1980; Baillie and Bollerslev, 1990; Bekaert and Hodrick, 1993; Bekaert, 1995). To this end, our empirical study is based on weekly data.

The empirical evidence of this study provides an important insight into the nature of risk premiums in the foreign-exchange market. The foreign-exchange excess return is found correlated with real interest-rate differential, long-short rate spread differential, and equity-premium differential between the domestic market and the US market. The evidence also shows that foreign exchange-risk premiums are not independent of the time-varying risks of the foreign exchange markets, bond and goods markets, and national stock markets. The results suggest that not only the first moment, but also the second moment of asset returns play an important role in determining the behavior of asset returns.

The rest of the paper is organized in sections as follows. The second section provides a theoretical framework that links foreign-exchange excess returns to various risk factors. Section 3 discusses the data and the empirical specification and estimation procedures of the models. Section 4 reports the empirical results for the foreign exchange excess return. Section 5 contains concluding remarks.

2. Theoretical Framework

Let s_{t+1}^{e} be the logarithm of the expected future spot rate for time *t+1* conditional on the information available at time *t*; s_t the logarithm of the spot exchange rate at time *t*; and f_t the logarithm of the corresponding forward exchange rate matured in time *t+1*. The expected foreign-exchange risk premium is defined as $s_{t+1}^{e} - f_t$, which can be decomposed into two components: the expected change in spot rate and the forward premium. In expression,

$$s_{t+1}^{e} - f_t = s_{t+1}^{e} - s_t - (f_t - s_t), \tag{1}$$

where $s_{t+1}^{e} - s_t$ is the expected change in the spot rate and $f_t - s_t$ is the forward premium. The balance of payments (BOP) theory suggests that economic agent demand for foreign currencies is motivated primarily by transactions and/or speculations on tradable goods and international financial assets. The financial assets may consist of short-term and long-term fixed income and equity securities across borders. Thus, the expected changes in future spot rates will be associated with expected changes in transactions involving goods and financial assets in the international markets.

In the floating exchange-rate regime, expected changes in exchange rates should correspond to changes in balances on the current account and on the capital account. These account balances are further dependent on expected changes in relative prices, interest rates, and expected stock returns between domestic and foreign markets. It follows that expected changes in exchange rates can be viewed as (or predicted by) a linear combination of changes in various international parities, including purchasing power parity (PPP), uncovered interest rate parity (UIRP), and international equity parity (IEP) conditions. Thus, we write:

$$s_{t+1}^{e} - s_t = \alpha(\Delta p_{t+1}^{e} - \Delta p_{t+1}^{e*}) + \beta(r_t - r_t^{*}) + \gamma(r_t^{L} - r_t^{L*}) + \delta(R_{t+1}^{e} - R_{t+1}^{e*}), \tag{2}$$

where Δp_{t+1}^{e} is the expected inflation rate from time *t* to *t+1*; r_t is the short-term interest rate; r_t^{L} is the long-term interest rate available at time *t*; R_{t+1}^{e} is the expected stock-market return from time *t* to *t+1*; and an asterisk denotes variables for the foreign country. The arguments on the right side of Equation (2) are the key variables that affect different components of a country's balance of payments. Specifically, the variable of the expected inflation-rate differential affects commodity flows in the current account, while the other arguments dictate various forms of capital flows in the capital account. The share of each component will be reflected, respectively, in the parameters α, β, γ, and δ. The restriction $\alpha + \beta + \gamma + \delta = 1$ is constrained by the sum of the components of the balance of payments. Equation (2) states that expected changes in spot exchange rates are associated with expected inflation-rate differentials, short-term interest-rate differentials, long-term interest-rate differentials, and differences in expected national stock returns.[2] By combining Equation (1) and Equation (2) and assuming covered that interest-rate parity, $f_t - s_t = r_t - r_t^*$, holds, we show:

$$s^e_{t+1} - f_t = -\alpha[(r_t - \Delta p^e_{t+1}) - (r^*_t - \Delta p^{e*}_{t+1})] + \gamma[(r^L_t - r_t) - (r^{L*}_t - r^*_t)] + \delta[(R^e_{t+1} - r_t) - (R^{e*}_{t+1} - r^*_t)] \quad (3)$$

Equation (3) represents a general specification of the foreign exchange-risk premium hypothesis. A number of the traditional models we discussed in the-previous section are nested in this model. For instance, by imposing the restriction of $\gamma = \delta = 0$, Korajczyk's (1985) real interest-rate differential hypothesis is achieved; and by restricting $\alpha = \gamma = 0$, Chiang's (1991) equity premium differential hypothesis is obtained. A special form of the model is that the forward rate, f_t, is an unbiased predictor of the future spot rate, s_{t+1}. This is true if the restriction that $\alpha = \delta = \gamma = 0$ holds. This restriction implies that the unbiased forward-rate hypothesis must satisfy three conditions: (a) the expected real returns on short-term interest rates are equal; (b) the long-short spreads between two markets are equal; and (c) the expected equity-premium differentials between two equity markets are zero.[3]

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[2] Several international parity conditions are nested in the specification of Equation (2). For instance, if $\alpha = 1$ and $\beta = \gamma = \delta = 0$, then we have the relative version of purchasing powered parity; $\beta = 1$ and $\alpha = \gamma = \delta = 0$, uncovered interest rate parity; $\gamma = 1$ and $\alpha = \beta = \delta = 0$, long-term interest-rate parity; $\delta = 1$ and $\alpha = \beta = \gamma = 0$, international equity-parity condition. Equation (2) thus suggests that each parity condition in conventional analysis can explain only partially expected changes in exchange rate.

[3] An important message emerging from Equation (3) is that the expected foreign-exchange risk premium is due essentially to the risk associated with future inflation rates (Korajczyk, 1985), interest rates, and stock returns (Chiang, 1991) relative to the current short-term risk-free rates. Note that the term $[(r^L_t - r_t) - (r^{L*}_t - r^*_t)]$ reflects the yield curve slope differential, capturing the liquidity risk differential.

As noted by Roll (1979), international-parity conditions provide no specific guidance to the direction and extent of causation between relative returns and exchange-rate changes. Placing the dependent and independent variables on each side of the test equation, such as Equation (3), varies among different researchers. Marston (1997) observes that the asset excess returns shown on the right side of Equation (3) are interrelated since their deviations from parity, and hence their differentials, are driven by similar information sets. Thus, in the empirical estimation, Equation (3) will be tackled in a vector autoregressive process. The VAR specification allows us to examine the dynamic relationship and the interrelationship among different components in Equation (3) simultaneously.

3. Data and Empirical Estimation

3.1 The Data

The data for exchange rates include Belgian francs, Canadian dollars, French francs, Deutsche marks, Italian lira, Japanese yen, Dutch guilders, Swiss francs, and British pounds. The spot exchange rates are weekly Friday closing quotations and are expressed in national currency units (NCU) per US dollar as taken from the WEFA group. Interest rates are weekly one-week Eurocurrency rates, and weekly stock-market indices are value-weighted indices for Belgium, Canada, France, Germany, Italy, Japan, the Netherlands, Switzerland, the United Kingdom, and the United States. Both interest rates and stock-market indices (expressed in local currency values) are the weekly Friday close, obtained from *Datastream International*. Consumer-prices indices (CPI) are taken from *International Financial Statistics*.[4] The sample spans the period from January 4, 1989 to January 1, 1999, covering the recent floating exchange rate experience.[5] The justification for using a weekly sampling scheme is

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[4] Eurocurrency rates are used in this study to reduce the issue of market segmentation or barriers because they are offshore deposits not subject to capital controls. Since the consumer-price indices are released on a monthly frequency, they are unlikely to have weekly observations. We assume a flat term structure of inflation rates, so that one-fourth times the monthly inflation rate gives us the weekly inflation rate. This approach is motivated by rigidity of consumer prices in the shorter time horizon.

[5] The sample period covers the time frame from 1980 to 1999 when the world capital market was considered more integrated and had fewer restrictions on capital movements throughout the industrial countries. The ending date is dictated by the availability of data. Also, it is noted that the European Monetary System (EMS) was created with the launching of the Euro on January 1, 1999.

motivated by the several empirical considerations. First, as noted by Baillie and Bollerslev (1990), to detect relatively short-lived risk premium or market inefficiency, it is important to conduct the test by using high-frequency data. Second, no previous empirical research analysis has been conducted on the basis of weekly data, where using this type of data can demonstrate volatility by using a conditional heteroscedasticity model.

Assuming effective arbitrage, weekly forward exchange rates are generated by covered interest-rate parity using weekly spot exchange rates and weekly one-week Eurocurrency rates. The foreign exchange excess returns (FXER) or forward rate forecast errors are measured as $s_{t+1} - f_t$, both s_{t+1} and f_t denote the natural logarithm of the future spot exchange rate and the forward exchange rate observed at time *t*, respectively. The inflation rate, Δp_t, is generated by the natural log-difference of consumer-price indices observed in *t* and *t-1*; the stock return, ΔR_t, is measured by the natural log-difference of the stock-price index observed at both *t* and *t-1*. The real interest-rate differential (RIRD) is defined as $[(r_t - \Delta p_{t+1}^e) - (r_t^* - \Delta p_{t+1}^{e*})]$; the long-short interest-rate spread differential (LSSD) is defined as $[(r_t^L - r_t) - (r_t^{L*} - r_t^*)]$; and the expected equity-premium differential (EPD) is defined as $[(R_{t+1}^e - r_t) - (R_{t+1}^{e*} - r_t^*)]$. An asterisk denotes variables of a foreign country.[6]

3.2 Empirical Estimations

As stated earlier, since international conditions provide no specific guidance to the direction and extent of causation among the deviations, it is more appropriate to investigate the system in a VAR-GARCH-in-mean form. The appeal of using a VAR specification is that the inter-relationships among the arguments can be examined.[7] Thus, VAR provides a framework

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[6] Since the weekly FXER, RID, LSSD, and EPD are relatively small, we annualize the variables in the empirical estimations to make our interpretation easier. It will not affect the general results of our analysis.

[7] For instance, Equation (3) can be alternatively expressed as:

$$[(r_t - \Delta p_{t+1}^e) - (r_t^* - \Delta p_{t+1}^{e*})]$$
$$= -\frac{1}{\alpha}(s_{t+1}^e - f_t) + \frac{\gamma}{\alpha}[(r_t^L - r_t) - (r_t^{L*} - r_t^*)] + \frac{\delta}{\alpha}[(R_{t+1}^e - r_t) - (R_{t+1}^{e*} - r_t^*)]$$

This expression reveals that real interest-rate differentials can be explained by the deviations of parity conditions in forward-spot rate, the difference of term-structure slopes, and equity-premium differentials.

to analyze a multivariate dynamic feedback relationship. Moreover, since the excess-return differentials are in the form of expectations, these variables are appropriately estimated by instrumental variables. Conventional econometric methods suggest that the lagged values are employed to serve as instruments. In addition, the GARCH-in-mean specification enables us to examine excess returns in relation to conditional variances. The significance of the estimated coefficients in test equations would help us to identify the significance of the risk factors in particular markets.

By using the lagged variables as the optimal instrument to engage one-period-ahead prediction, we write a VAR-GARCH-in-mean representation as:

$$\begin{bmatrix} s_{t+1}-f_t \\ (r_t-\Delta p_{t+1})-(r_t^*-\Delta p_{t+1}^*) \\ (r_t^L-r_t)-(r_t^{L*}-r_t^*) \\ (R_{t+1}-r_t)-(R_{t+1}^*-r_t^*) \end{bmatrix} = \begin{bmatrix} \phi_{10} \\ \phi_{20} \\ \phi_{30} \\ \phi_{40} \end{bmatrix} + \begin{bmatrix} \phi_{11}(L) & \phi_{12}(L) & \phi_{13}(L) & \phi_{14}(L) \\ \phi_{21}(L) & \phi_{22}(L) & \phi_{23}(L) & \phi_{24}(L) \\ \phi_{31}(L) & \phi_{32}(L) & \phi_{33}(L) & \phi_{34}(L) \\ \phi_{41}(L) & \phi_{42}(L) & \phi_{43}(L) & \phi_{44}(L) \end{bmatrix} \cdot \begin{bmatrix} s_{t+1}-f_t \\ (r_t-\Delta p_{t+1})-(r_t^*-\Delta p_{t+1}^*) \\ (r_t^L-r_t)-(r_t^{L*}-r_t^*) \\ (R_{t+1}-r_t)-(R_{t+1}^*-r_t^*) \end{bmatrix} + \begin{bmatrix} \phi_{15} & \phi_{16} & \phi_{17} & \phi_{18} \\ 0 & \phi_{25} & 0 & 0 \\ 0 & 0 & \phi_{35} & 0 \\ 0 & 0 & 0 & \phi_{45} \end{bmatrix} \begin{bmatrix} h_{11,t+1} \\ h_{22,t+1} \\ h_{33,t+1} \\ h_{44,t+1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1,t+1} \\ \varepsilon_{2,t+1} \\ \varepsilon_{3,t+1} \\ \varepsilon_{4,t+1} \end{bmatrix} \tag{4}$$

with $\varepsilon_{t+1} \mid I_t \sim N[0, H_{t+1}(I_t)]$,

$$H_t = \begin{bmatrix} h_{11,t} & h_{12,t} & h_{13,t} & h_{14,t} \\ h_{21,t} & h_{22,t} & h_{23,t} & h_{24,t} \\ h_{31,t} & h_{32,t} & h_{33,t} & h_{34,t} \\ h_{41,t} & h_{42,t} & h_{43,t} & h_{44,t} \end{bmatrix}, \tag{5}$$

$$H_t = C + \sum_{k=1}^{q} \varepsilon'_{t-k} D_k \varepsilon_{t-k} + \sum_{k=1}^{p} G_k H_{t-k}, \tag{5'}$$

where $\phi_{ij}(L) = \sum_{k=1}^{l_{ij}} \phi_{ijk} L^K$, l_{ij} is the degree of the polynomial $\phi_{ij}(L)$; I_t is the information set available at time *t*; and C , D_k , and G_k are 4×4 matrices. However, under this specification, H_t is not guaranteed to be positive definite for all values of ε_t in the sample space. To overcome this problem, we adopt the parameterization suggested by Baba, Engle, Kraft and Kroner (1987) that easily imposes these restrictions (the BEKK model). By using the parameterization scheme, we can rewrite Equation (5)' as follows:

$$H_t = C'C + \sum_{k=1}^{q} D'_k \varepsilon_{t-k} \varepsilon'_{t-k} D_k + \sum_{k=1}^{p} G'_k H_{t-k} G_k, \tag{6}$$

where the *C*, *D*, and *G* are 4×4 matrices, and *C* is restricted to be upper triangular. A specification test will be used to investigate the adequacy of this statistical model of the conditional covariance matrix H_t. Since our primary interest is to provide empirical evidence on pricing exchange-rate risk, the cross components of conditional variances for other excess-return equations are restricted to zero in order to reduce unnecessary parameter estimations.

Equation (4) and Equation (6) can be estimated by maximum-likelihood techniques. For sample size *T*, the log-likelihood function is the sum of the conditional log-likelihood for each observation:

$$L_T(\theta_f) = \sum_{t=1}^{T} \ell_t(\theta_f),$$

$$\ell_t(\theta_f) = -\frac{1}{2}\ln(2\pi) - \frac{1}{2}\left(\ln\left|H_t^{-1}\right|\right) - \frac{1}{2}\varepsilon'_t H_t^{-1}\varepsilon_t, \tag{7}$$

and this log-likelihood function can be maximized with respect to the unknown parameter θ_f (*C*, *D*, *G*) for the model, which is a vector of all parameters to be estimated. We adopt the quasi-maximum likelihood estimation (QML) proposed by Bollerslev and Wooldridge (1992) that allows inference in the presence of departure from conditional normality. Under fairly weak conditions, the resulting estimates are consistent even when the conditional distribution of the residuals is non-normal.[8] The QML estimates can be obtained by maximizing Equation (7) and calculating a robust estimate of the covariance of parameter estimates using the matrix of second derivatives and the average of the period-by-period outer products of gradient. Non-linear optimization techniques are used to calculate the maximum likelihood estimates based on the Broyden, Fletcher, Goldfarb, and Shanno (BFGS) algorithm.

A special feature of this model is its richness of information content. It comprises both the level of economic fundamentals of risk factors as well as their underlying conditional variances. This will also generate a problem since the information may be redundant, causing statistical insignificance for some estimated coefficients.

4. Empirical results

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[8] Empirically, the unconditional distributions of financial variables are found to depart from normal. Most of the distributions are leptokurtic (fat-tailed) relative to normal distributions. It may be due to the presence of linear or non-linear dependency of the variables. The variables in this study also suffer from skewness and excess kurtosis. The basic statistics are not reported and are available upon request from the authors.

4.1. Tests for Stationarity

It is well recognized that traditional statistical tests used for inference are based on the assumption that the underlying series are stationary ergodic processes. The usual distributional results and tests of significance are no longer valid and can be misleading if the series under investigation are non-stationary. Unit-root tests provide a simple method for testing whether a series is non-stationary and therefore, a useful check of appropriateness and statistical reliability of the time-series models. Table 1 presents the results for Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit-root tests recommended by Engle and Granger (1987) and Phillips and Perron (1988), respectively, for the variables used in this study. The evidence shows that the null hypothesis of $I(1)$ for the foreign-exchange excess return ($s_{t+1} - f_t$, FXER), real interest-rate differential $[(r_t - \Delta p_{t+1}) - (r_t^* - \Delta p_{t+1}^*)$, RIRD], long-short spread differential, $[(r_t^L - r_t) - (r_t^{L*} - r_t^*)$, LSSD], and expected equity-premium differential $[(R_{t+1} - r_t) - (R_{t+1}^* - r_t^*)$, EEPD] is rejected, indicating that these series represent a stationary process.

4.2. Evidence from Significance Tests

To determine appropriate lag lengths of the VAR process, we apply the multivariate generalizations of AIC and SBC criteria. Statistics in Table 2 suggest that lag 1 is appropriate. This decision is also consistent with the principle of parsimony in modeling time series. With this information, we estimate the model of VAR(1)-GARCH-in-mean as represented by Equation (4) and Equation (6). Table 3 reports the estimates for the exchange-risk premium equation (the first row of the VAR model) in the vector process. It can be viewed as regressing FXER_t on FXER_{t-1}, RID_{t-1}, LSSD_{t-1}, EPD_{t-1}, and a vector of conditional variances. The absolute *t*-statistics of the coefficients are given in the parentheses below the estimated coefficients. By checking individual coefficients, most of the AR(1) terms of FXER_t are insignificant except for Italy and the United Kingdom, indicating that the exchange-rate risk premium does not present significant autocorrelation. For the coefficient of the real interest-rate differential, the evidence shows that the market for the United Kingdom, the Netherlands, and Switzerland are consistent with theoretical expectations. The real interest-rate differential has explanatory power. Similar results are found in the coefficient of the equity-premium differential, where the coefficients for Italy and the Netherlands are significant. However, the evidence emerging from the long-short interest- rate differential is rather interesting, as we found the majority of the countries are statistically significant, including Belgium, Canada, Germany, the Netherlands, and Switzerland. This new evidence has not been shown in previous studies. In sum, the Netherlands and Switzerland are explained well by this set of variables; however, France and Japan are not.

Turning to the estimates of the conditional variances, we find that the exchange-rate excess returns for France and Japan gain more explanatory power by using their own conditional exchange-rate variances. Other countries, such as Belgium, France, Germany, Italy, and Switzerland, show that stock-return volatility has more predicting power in projecting exchange-rate excess returns. In general, the explanatory power for individual risk factors varies from country to country. This is understandable since our model consists of a relatively larger information set and some of the explanatory variables appear to carry redundant information, thus reducing the power of the significance.

4.3. Evidence from Joint Tests

To check the significance of the information set by using the level of economic fundamentals vis-à-vis the conditional variances to explain the foreign-exchange excess return (FXER), we conduct two joint tests. First, the null hypothesis for $\phi_{11}(1)=\phi_{12}(1)=\phi_{13}(1)=\phi_{14}(1)=0$ is designed to examine the joint significance of the economic fundamentals. Second, the null hypothesis for $\phi_{15}=\phi_{16}=\phi_{17}=\phi_{18}=0$ is to test the joint significance of conditional variances. The LRT1 in Table 3 is the log-likelihood ratio for examining the significance of the information content of $FXER_{t-1}$, RID_{t-1}, $LSSD_{t-1}$, and EPD_{t-1} on $FXER_t$. The statistics are significant for seven out of nine countries. This finding suggests that at least one of the fundamental variables has significant explanatory power on FXER.[9] The LRT2 is the

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[9] This can also be viewed as a piece of information for rejecting the efficient-market hypothesis.

log-likelihood ratio for examining the joint significance of conditional variances. The evidence shows that the null hypothesis is rejected in seven out of nine cases, indicating that asset-return volatility does play a significant role in the test equation. Putting these two pieces of evidence together, it can be concluded that the test equation is rejected at least once. The results thus support the risk premium hypothesis.

Finally, we examine the correlations on the level of residuals and the product terms of the residuals up to 10 orders by calculating the Ljung-Box statistics, $Q(10)$ and $Q^2(10)$, from the estimated VAR model. The $Q(10)$ values in Table 4 indicate no evidence that the null should be rejected. Next, the statistics by $Q^2(10)$ are slightly higher. However, with the exceptions of a few cases, we don't find noticeable evidence to reject the null hypothesis. The null again cannot be rejected at a high level of significance. In general, the model is adequate and is appropriate by employing a VAR-GARCH(1,1) specification.

5. Concluding Remarks

Building on the established theoretical foundation laid out by Roll (1977), Korajczyk (1985), and Chiang (1991), this paper constructs a unified framework and extends their models by adding a long-short interest-rate spread differential as an argument to explain the foreign-exchange risk premium. Specifically, we argue that the foreign-exchange excess return is associated with economic fundamental factors as indicated by real interest-rate differential, long-short interest-rate spread differential, and equity-premium differential. Empirical analysis from this study provides supporting evidence for these arguments. More interestingly, the long-short rate spread differential is a new variable discovered in this study. The ignorance of this term in the literature is due to the fact that the traditional model includes only short-term interest-rate differential rather than the long-term interest-rate differential in explaining the exchange-rate movements. As a result, the liquidity-premium differential has never played a significant role in predicting foreign-exchange excess return.

In testing the risk-premium hypothesis, we also include conditional variances for the fundamental variables. The testing results suggest that the null hypothesis of independence between foreign-exchange excess return and the fundamental conditional variances is rejected for all of the countries under investigation, supporting the time-varying risk-premium hypothesis for currency markets.

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Table 1. Unit-Root Tests for Foreign Exchange Excess Return (FXER), Real Interest Rate Differential (RIRD), Long-Short Interest Rate Spread Differential (LSSD), and Equity Premium Differential (EPD).

Country	**FXER**		**RIRD**		**LSSD**		**EPD**	
	ADF	**PP**	**ADF**	**PP**	**ADF**	**PP**	**ADF**	**PP**
Belgium	-31.80(0)***	-31.85***	-9.26(4)***	-10.68***	-19.34(0)***	-19.33***	-35.57(0)***	-35.52***
Canada	-32.63(0)***	-32.62***	-8.48(5)***	-11.64***	-7.89(6)***	-12.90***	-32.76(0)***	-32.94***
France	-30.78(0)***	-30.83***	-9.27(4)***	-12.55***	-12.78(5)***	-17.25***	-32.77(0)***	-32.77***
Germany	-30.86(0)***	-30.90***	-8.61(4)***	-10.26***	-5.80(1)***	-7.36***	-33.78(0)***	-33.74***
Italy	-32.02(0)***	-32.05***	-6.57(4)***	-8.06***	-18.94(0)***	-19.04***	-30.49(0)***	-30.42***
Japan	-30.17(0)***	-30.25***	-11.96(11)***	-11.96***	-6.63(5)***	-8.82***	-33.40(0)***	-33.35***
Netherlands	-36.74(0)***	-37.07***	-10.33(4)***	-11.28***	-6.45(1)***	-7.87***	-34.47(0)***	-34.45***
Switzerland	-31.92(0)***	-31.93***	-9.39(5)***	-11.70***	-6.27(12)***	-13.48***	-34.82(0)***	-34.85***
United Kingdom	-30.36(0)***	-30.40***	-8.31(13)***	-11.24***	-6.94(1)***	-8.22***	-34.56(0)***	-34.58***

Notes: The unit-root tests reported here are the Augmented Dicky-Fuller (ADF) and Phillips-Perron (PP) tests with time trend. The Phillips-Perron test allows for more general serial correlation and heteroskedasticity of unknown form in distribution. We set the lags truncation at 4 in the Phillips-Perron tests. The number in the parenthesis is the lag length selected in the ADF test. The lag length selection is based on Ljung-Box Q statistics; more lags will be added in the regression model until the Q(12) is not significant at 5% level. The *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. The critical values are -2.57 (10%), -2.86 (5%), and -3.43 (1%) taken from Fuller (1976).

Table 2. Multivariate Generalizations of AIC and SBC for Vector Auto-regressions of Foreign Exchange Excess Return (FXER), Real Interest Rate Differential (RIRD), Long-Short Interest Rate Spread Differential (LSSD), and Equity Premium Differential (EPD).

Country	**AIC**				**SBC**			
Number of Lags	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Belgium	-632.42	-549.66	-513.47	-495.06	-622.62	-532.03	-488.01	-461.75
Canada	-1134.07	-1057.24	-1010.13	-985.71	-1124.28	-1039.61	-984.67	-952.41
France	-390.76	-295.26	-259.58	-237.79	-380.96	-277.63	-234.11	-204.49
Germany	-1000.33	-907.83	-848.35	-811.27	-990.53	-890.19	-822.88	-777.96
Italy	-577.96	-514.78	-475.26	-451.62	-592.96	-497.14	-449.79	-418.31
Japan	-798.34	-701.42	-652.92	-632.93	-788.54	-683.79	-627.46	-599.63
Netherlands	-945.07	-846.24	-792.74	-758.63	-935.27	-828.61	-767.27	-725.32
Switzerland	-642.40	-581.81	-552.89	-556.94	-632.61	-564.17	-527.42	-523.67
United Kingdom	-876.76	-775.39	-721.79	-686.25	-866.97	-757.76	-696.32	-652.95

Notes: $AIC = \log|\Sigma| + 2*N / T$ and $SBC = \log|\Sigma| + N*\log(T) / T$, where $|\Sigma|$ is the determinant of the variance/covariance matrix of the residuals, T is the useable observation, and N is the total number of the parameters estimated in all equations. The appropriate lag length for the VAR minimizes the AIC and/or SBC criteria.

Table 3. Estimates for VAR-GARCH (1,1) in Mean Model for the Foreign Exchange Excess Returns.

Variable	ϕ_{i0}	$\phi_{i1}(1)$	$\phi_{i2}(1)$	$\phi_{i3}(1)$	$\phi_{i4}(1)$	ϕ_{i5}	ϕ_{i6}	ϕ_{i7}	ϕ_{i8}	**LRT$_1$**	**LRT$_2$**
					Belgium						
FXER	0.7010	-0.0169	-0.0091	3.9193**	0.0123	-0.4402*	2.5239	2.2008	0.0549**	5.87	8.69*
	(1.42)	(0.53)	(0.08)	(2.19)	(0.62)	(1.93)	(0.63)	(0.89)	(2.23)		
RIRD	0.0187**	-0.0018	0.7971***	0.1428	-0.0030		-0.1198				
	(2.10)	(0.49)	(28.91)	(0.88)	(1.38)		(0.65)				
LSSD	-0.0016***	-0.00003	0.0044***	0.7913***	-0.0002			0.0864			
	(4.19)	(0.28)	(2.99)	(31.32)	(1.21)			(1.51)			
ESRD	-0.2985*	0.1938***	-0.1652	1.7486	-0.1519***				0.0567**		
	(1.86)	(4.60)	(0.73)	(0.94)	(3.95)				(1.98)		
					Canada						
FXER	0.0737	-0.0157	0.0406	2.7171***	-0.0089	-0.4959	0.6772	-55.2763	0.0527	8.58*	7.87*
	(0.15)	(0.45)	(0.46)	(2.71)	(0.66)	(0.29)	(1.07)	(1.40)	(0.47)		
RIRD	0.0180	-0.0157*	0.7721***	0.3046	0.0050		-0.3641				
	(1.48)	(1.80)	(23.02)	(0.84)	(1.18)		(1.23)				
LSSD	0.0012***	0.0013***	-0.0036**	0.7498***	0.0003			-3.6522*			
	(2.71)	(2.97)	(2.05)	(17.71)	(0.96)			(1.93)			
ESRD	0.1334	-0.2067***	0.0314	-1.0463	-0.0582*				-0.1346		
	(0.34)	(3.03)	(0.25)	(0.48)	(1.65)				(0.77)		

Table 3 (continued)

Variable	ϕ_{i0}	$\phi_{i1}(1)$	$\phi_{i2}(1)$	$\phi_{i3}(1)$	$\phi_{i4}(1)$	ϕ_{i5}	ϕ_{i6}	ϕ_{i7}	ϕ_{i8}	**LRT$_1$**	**LRT$_2$**
						France					
FXER	-0.2582	0.0210	-0.5563***	-0.9777	0.0163	0.2240***	5.4751**	-4.1903	-0.0665***	169.34***	234.87***
	(1.63)	(1.57)	(3.88)	(1.54)	(1.13)	(2.83)	(2.47)	(1.03)	(11.80)		
RIRD	0.0067	0.0007	0.8554***	0.0243	-0.0028		-0.0179				
	(0.24)	(0.03)	(101.85)	(0.70)	(0.28)		(0.05)				
LSSD	0.0006	-0.0010	-0.0029***	0.7610***	0.00003			-0.1185			
	(0.22)	(1.06)	(3.61)	(11.72)	(0.01)			(0.12)			
ESRD	-0.0602	0.0162	-0.6798***	-1.9502***	-0.0108***				-0.0182*		
	(0.45)	(1.29)	(20.7)	(16.22)	(5.07)				(1.64)		
						Germany					
FXER	0.8935***	-0.0154	-0.2310	4.4760*	0.0070	0.0387	-3.3176	687.43	-0.1416**	5.57	7.85*
	(2.62)	(0.57)	(1.44)	(1.88)	(0.40)	(0.65)	(0.91)	(1.13)	(2.25)		
RIRD	0.0113	-0.0014	0.9175***	0.2512	-0.0001		-0.0344				
	(1.32)	(0.37)	(74.50)	(1.25)	(0.04)		(0.08)				
LSSD	-0.0006	-0.00001	0.0009	0.9200***	-0.0001			-1.8361			
	(1.64)	(0.07)	(0.60)	(78.02)	(1.18)			(0.36)			
ESRD	0.4584	0.0540	-0.1907	7.3431**	-0.0770***				-0.0630		
	(1.17)	(1.16)	(0.66)	(2.25)	(2.61)				(0.97)		

Table 3 (continued)

Variable	ϕ_{i0}	$\phi_{i1}(1)$	$\phi_{i2}(1)$	$\phi_{i3}(1)$	$\phi_{i4}(1)$	ϕ_{i5}	ϕ_{i6}	ϕ_{i7}	ϕ_{i8}	**LRT$_1$**	**LRT$_2$**
					Italy						
FXER	-0.6006***	-0.0820**	-0.1535	-2.2564	0.0530***	-1.1632***	-84.9412***	128.20***	0.5480***	18.99***	406.63***
	(4.43)	(2.20)	(0.54)	(1.27)	(2.90)	(11.60)	(3.03)	(6.18)	(4.23)		
RIRD	0.0003	-0.0032	0.8361***	-0.0678	-0.0039**		-0.0734				
	(0.02)	(0.67)	(44.12)	(0.42)	(2.23)		(0.16)				
LSSD	0.0004	0.0008	-0.0074***	0.5305***	0.0001			-3.1999***			
	(0.29)	(0.81)	(2.97)	(9.27)	(0.12)			(4.42)			
ESRD	-0.2781***	-0.1443***	-0.3135*	-2.7210	0.0664***				0.0167**		
	(3.45)	(3.05)	(1.69)	(1.45)	(2.76)				(2.00)		
					Japan						
FXER	0.0464	0.0310	0.1844*	2.6911	0.0045	0.1511*	-0.4432	-117.34	-0.0577	8.06*	4.60
	(0.15)	(1.13)	(1.71)	(1.34)	(0.23)	(1.92)	(0.34)	(0.90)	(1.23)		
RIRD	-0.0010	-0.0082	0.7930***	-0.3298	0.0043		0.3719				
	(0.03)	(1.25)	(33.80)	(0.63)	(1.14)		(1.33)				
LSSD	-0.0020***	0.0004*	0.0013	0.8460***	-0.0001			1.4051			
	(4.97)	(1.77)	(1.22)	(51.82)	(0.86)			(0.85)			
ESRD	-0.3378	0.0214	-0.2312	6.5237**	-0.0703***				0.0572		
	(1.32)	(0.37)	(1.28)	(2.38)	(2.67)				(1.56)		

Table 3 (continued)

Variable	ϕ_{i0}	$\phi_{i1}(1)$	$\phi_{i2}(1)$	$\phi_{i3}(1)$	$\phi_{i4}(1)$	ϕ_{i5}	ϕ_{i6}	ϕ_{i7}	ϕ_{i8}	**LRT$_1$**	**LRT$_2$**
Netherlands											
FXER	-1.5362	-0.0465	-0.5306**	11.3141***	0.0546*	0.6024	4.5188**	50.4898	-0.1213	12.82**	8.03*
	(0.99)	(0.81)	(2.15)	(3.01)	(1.87)	(1.13)	(1.99)	(0.17)	(1.38)		
RIRD	0.0009	-0.0070*	0.8339***	0.4876	-0.0030		0.0716				
	(0.07)	(1.69)	(26.05)	(1.51)	(0.78)		(0.26)				
LSSD	-0.0003	0.0004*	0.0013	0.8967***	-0.0002			-0.9447			
	(0.89)	(1.84)	(1.25)	(51.52)	(1.56)			(0.31)			
ESRD	0.2567	0.0645	-0.6292***	4.7681	-0.1152***				-0.0475		
	(0.97)	(1.51)	(3.15)	(1.05)	(3.73)				(0.96)		
Switzerland											
FXER	0.1593	-0.0369	-0.4239***	3.7722**	0.0333	0.0065	8.7101**	-15.6083	-0.0744***	18.27***	18.55***
	(0.68)	(1.35)	(2.93)	(1.97)	(1.42)	(0.24)	(1.99)	(1.04)	(2.83)		
RIRD	0.0045	0.0002	0.9157***	0.0044	-0.0003		-0.1030				
	(0.83)	(0.08)	(60.48)	(0.03)	(0.17)		(0.39)				
LSSD	-0.0015***	0.00004	0.0010	0.7687***	-0.0003*			0.3203			
	(3.04)	(0.02)	(0.71)	(18.82)	(1.70)			(0.70)			
ESRD	0.1704	0.0793**	-0.0275	0.4951	-0.1608***				-0.0257		
	(0.93)	(2.30)	(0.15)	(0.29)	(6.35)				(0.58)		

Table 3 (continued)

Variable	ϕ_{i0}	$\phi_{i1}(1)$	$\phi_{i2}(1)$	$\phi_{i3}(1)$	$\phi_{i4}(1)$	ϕ_{i5}	ϕ_{i6}	ϕ_{i7}	ϕ_{i8}	**LRT$_1$**	**LRT$_2$**
						United Kingdom					
FXER	2.0195	0.0644*	-0.1531*	3.4832	0.0203	0.0241	0.4086	353.44	-0.4869	11.74**	1.91
	(0.79)	(1.94)	(1.77)	(1.48)	(0.92)	(0.16)	(0.17)	(0.51)	(0.84)		
RIRD	0.0250	-0.0067	0.7621***	-1.0669*	-0.0017		-0.4042				
	(0.69)	(1.04)	(17.74)	(1.93)	(0.36)		(0.94)				
LSSD	0.0001	0.0001	0.0007	0.8621***	-0.0004*			-7.9609*			
	(0.32)	(0.38)	(0.77)	(41.87)	(1.94)			(1.78)			
ESRD	0.2826	0.0856*	0.1544	3.2277	-0.1333***				-0.0767		
	(0.14)	(1.91)	(1.21)	(0.95)	(3.49)				(0.17)		

Notes: The estimated equation is given as:

$$\begin{bmatrix} s_{t+1}-f_t \\ (r_t-\Delta p_{t+1})-(r_t^*-\Delta p_{t+1}^*) \\ (r_t^L-r_t)-(r_t^{L*}-r_t^*) \\ (R_{t+1}-r_t)-(R_{t+1}^*-r_t^*) \end{bmatrix} = \begin{bmatrix} \phi_{10} \\ \phi_{20} \\ \phi_{30} \\ \phi_{40} \end{bmatrix} + \begin{bmatrix} \phi_{11}(L) & \phi_{12}(L) & \phi_{13}(L) & \phi_{14}(L) \\ \phi_{21}(L) & \phi_{22}(L) & \phi_{23}(L) & \phi_{24}(L) \\ \phi_{31}(L) & \phi_{32}(L) & \phi_{33}(L) & \phi_{34}(L) \\ \phi_{41}(L) & \phi_{42}(L) & \phi_{43}(L) & \phi_{44}(L) \end{bmatrix} \cdot \begin{bmatrix} s_{t+1}-f_t \\ (r_t-\Delta p_{t+1})-(r_t^*-\Delta p_{t+1}^*) \\ (r_t^L-r_t)-(r_t^{L*}-r_t^*) \\ (R_{t+1}-r_t)-(R_{t+1}^*-r_t^*) \end{bmatrix} + \begin{bmatrix} \phi_{15} & \phi_{16} & \phi_{17} & \phi_{18} \\ 0 & \phi_{25} & 0 & 0 \\ 0 & 0 & \phi_{35} & 0 \\ 0 & 0 & 0 & \phi_{45} \end{bmatrix} \begin{bmatrix} h_{11,t+1} \\ h_{22,t+1} \\ h_{33,t+1} \\ h_{44,t+1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1,t+1} \\ \varepsilon_{2,t+1} \\ \varepsilon_{3,t+1} \\ \varepsilon_{4,t+1} \end{bmatrix},$$

a. LRT1 is the log-likelihood ratio statistic for examining the joint significance of FXER$_{t-1}$, RID$_{t-1}$, and EPD$_{t-1}$ on FXER$_t$ by testing the restriction. $\phi_{11}(1) = \phi_{12}(1) = \phi_{13}(1) = \phi_{14}(1) = 0$. Evidence shows that the null is rejected for 7 out of 9 countries (not significant for Belgium and Germany).

b. LRT2 is the log-likelihood ratio statistic for examining the joint significance of conditional variances by testing the restriction $\phi_{15} = \phi_{16} = \phi_{17} = \phi_{18} = 0$. Evidence shows that the null is rejected for 7 out of 9 countries (except for Japan and the United Kingdom).

c. The *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 4. Specification (Ljung-Box) Tests for Residuals of Multivariate GARCH Model

Residuals		$\varepsilon_{\text{FXER}}$	$\varepsilon_{\text{RIRD}}$	$\varepsilon_{\text{LSSD}}$	ε_{EPD}	$\varepsilon_{\text{FXER}}$	$\varepsilon_{\text{RIRD}}$	$\varepsilon_{\text{LSSD}}$	ε_{EPD}
		Belgium				***Canada***			
$Q(10)$		12.17	10.81	9.53	12.95	8.59	10.70	15.98*	8.16
$Q^2(10)$	$\varepsilon_{\text{FXER}}$	12.10				12.21			
$Q^2(10)$	$\varepsilon_{\text{RIRD}}$	11.80	18.13*			19.76**	18.30*		
$Q^2(10)$	$\varepsilon_{\text{LSSD}}$	14.94	16.18*	16.77*		12.31	12.16	18.07*	
$Q^2(10)$	ε_{EPD}	18.39**	13.39	19.04**	10.45	9.20	17.70*	11.84	14.96
		France				***Germany***			
$Q(10)$		13.00	12.61	16.70*	12.86	9.97	10.07	14.51	11.15
$Q^2(10)$	$\varepsilon_{\text{FXER}}$	19.51**				18.06*			
$Q^2(10)$	$\varepsilon_{\text{RIRD}}$	16.87*	8.81			23.02**	15.34		
$Q^2(10)$	$\varepsilon_{\text{LSSD}}$	9.31	7.19	2.20		16.45*	12.67	16.43*	
$Q^2(10)$	ε_{EPD}	15.99*	15.18	12.37	20.37**	13.80	17.41*	13.88	15.88
		Italy				***Japan***			
$Q(10)$		11.30	9.95	19.38**	12.05	16.44*	10.37	18.11*	15.90
$Q^2(10)$	$\varepsilon_{\text{FXER}}$	11.53				13.58			
$Q^2(10)$	$\varepsilon_{\text{RIRD}}$	15.16	22.45**			13.14	17.96*		
$Q^2(10)$	$\varepsilon_{\text{LSSD}}$	17.66*	17.93*	18.23*		14.59	19.73**	15.17	
$Q^2(10)$	ε_{EPD}	15.01	19.84**	29.47	16.39*	12.30	10.53	15.79	11.79
		Netherlands				***Switzerland***			
$Q(10)$		16.15*	11.37	11.01	13.70	9.09	9.18	16.49*	10.05
$Q^2(10)$	$\varepsilon_{\text{FXER}}$	0.22				14.53			
$Q^2(10)$	$\varepsilon_{\text{RIRD}}$	0.32	0.83			7.63	14.66		
$Q^2(10)$	$\varepsilon_{\text{LSSD}}$	0.15	0.19	0.15		17.49*	16.14*	15.13	
$Q^2(10)$	ε_{EPD}	0.19	0.28	0.76	0.19	8.26	10.20	18.10*	20.58**
		United Kingdom							
$Q(10)$		8.81	6.93	11.39	9.60				
$Q^2(10)$	$\varepsilon_{\text{FXER}}$	11.09							
$Q^2(10)$	$\varepsilon_{\text{RIRD}}$	10.39	9.74						
$Q^2(10)$	$\varepsilon_{\text{LSSD}}$	13.77	18.75**	17.71*					
$Q^2(10)$	ε_{EPD}	15.26	11.80	18.90**	16.66*				

Notes: $Q(10)$ and $Q^2(10)$ are the Ljung-Box tests for 10th-order serial correlation in $\hat{\varepsilon}_{it}\hat{h}_{iit}^{-1/2}$ and $\hat{\varepsilon}_{it}\hat{h}_{iit}^{-1/2}\hat{\varepsilon}_{jt}\hat{h}_{jjt}^{-1/2}$, respectively. *, **, and *** denote statistical significance at 10%, 5%, and 1%, respectively, for the LB test based on the asymptotic p-values.