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Research article

The historical transition of return transmission, volatility spillovers, and dynamic conditional correlations: A fresh perspective and new evidence from the US, UK, and Japanese stock markets

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Abstract: This paper quantitatively investigated the historical transition of return transmission, volatility spillovers, and correlations between the US, UK, and Japanese stock markets. Applying a vector autoregressive (VAR)-dynamic conditional correlation (DCC)-multivariate exponential generalized autoregressive conditional heteroscedasticity (MEGARCH) model, we derived new evidence for four historical periods between 1984 and 2024. First, we found that the return transmission from the US to the other markets has historically become stronger, whereas recently, the return transmission from the UK to the US has disappeared. Second, we clarified that volatility spillovers from the US to the other markets have historically become stronger, whereas recently, volatility spillovers from the UK to the US have also disappeared. Third, our analyses of the historical constant correlations and DCCs revealed that stock market connectedness has gradually tightened between the US and Japan and between the UK and Japan, whereas recently, the connectedness between the US and UK has weakened. Fourth, our VAR-DCC analyses also revealed that volatility spillovers between the US, UK, and Japanese stock markets have been asymmetric. Fifth, we further showed that the skew-*t* errors incorporated into our VAR-DCC model are effective in estimating the dynamic stock return linkages between the US, the UK, and Japan. Finally, based on our findings, we derived many significant and beneficial interpretations and implications for historically and deeply considering return transmission, volatility spillovers, and DCCs between international stock markets.

Keywords: Brexit; COVID-19; DCC; European debt crisis; historical transition; MEGARCH; return transmission; VAR; volatility spillover

JEL codes: G00, G10, G12, G15

1. Introduction

Trends in international financial market integration, driven by the globalization of the world economy, have sparked a significant amount of research on the strengthening of global financial market relationships. These studies include those concerning market integration (e.g., Bekaert & Harvey, 1995; Fratzscher, 2002; Hunter, 2006; Wang & Moore, 2008; Savva & Aslanidis, 2010; Agyei-Ampomah, 2011; Horváth & Petrovski, 2013; Bae & Zhang, 2015; Virk & Javed, 2017; Wu, 2020), volatility spillovers (e.g., McMillan & Speight, 2010; Yilmaz, 2010; Diebold & Yilmaz, 2012; Sadorsky, 2012; Ji et al., 2018; Koutmos, 2018; Chen et al., 2022; Jiang et al., 2022; Papathanasiou et al., 2022; Samitas et al., 2022a, 2022b; Papathanasiou et al., 2023), and market connectedness (e.g., Billio et al., 2012; Baruník et al., 2016; Zhang, 2017; Gong et al., 2019; Ji et al., 2019; Liang et al., 2020; Reboredo & Ugolini, 2020; Zhang & Broadstock, 2020; Geng et al., 2021; So et al., 2021; Akyildirim et al., 2022; Asadi et al., 2022; Bouri et al., 2022; Goodell et al., 2023; Papathanasiou et al., 2024). The literature review section and Table 1 of Tsuji (2020) and Tables 1–5 of Asadi et al. (2022) are also useful to understand the recent related studies. In summary, these studies investigated the existence and direction of market linkages and interactions using different approaches. That is, these studies tested similar issues such as market integration, volatility spillovers, and connectedness by altering methods, typically using a single sample period.

In contrast, we suggest a new perspective—it may also be the case that there are historical stages and shifts in the linkages between international stock markets. That is, there have been some historical transitions in stock market connections and interactions. We particularly suggest that there may have been a slight reversal of globalization caused by the COVID-19 pandemic and that this may have exerted some effect on the dynamic linkages between international stock markets. Therefore, investigating the historical transition of return transmission, volatility spillovers, and correlations between international stock markets is necessary and significant to fill a research gap left by existing studies. With this motivation in mind, the goal of this study is to reveal whether there is a historical transition of return transmission, volatility spillovers, and correlations between major international stock markets with a particular focus on the recent state. To perform robust analysis for this purpose, we carefully construct four historical periods of analysis, which span the period of 1984 to 2024, and apply an extended econometric model, i.e., a vector autoregressive (VAR)-dynamic conditional correlation (DCC)-multivariate exponential generalized autoregressive conditional heteroscedasticity (MEGARCH) model (Tsuji, 2018; 2020) that incorporates asymmetric spillovers and skew-*t* errors to the stock market return data of the US, the UK, and Japan.

Our research questions are as follows. First, is there any historical transition in return transmission between the US, UK, and Japanese stock markets? Second, is there any historical transition in volatility spillovers between the US, UK, and Japanese stock markets? Third, is there any historical transition in the DCCs between the three stock markets? Fourth, is the incorporation of asymmetric spillovers effective in analyzing the dynamic interactions between these three stock markets? Finally, is the incorporation of skew-*t* errors effective in analyzing the dynamic linkages between these three markets?

Using our analysis, we make several important contributions to literature. First, we clarify that the return transmission from the US to the other markets has become stronger, whereas in our most recent period from 2004 to 2024, we cannot distinguish any return transmission from the UK to the other markets. This implies that until recently, the strength of the effects of the US and UK stock markets may have shifted, and this demonstrates the presence of the historical transition of stock return transmission between the US, UK, and Japan. This new evidence is one significant contribution of this study. Second, we reveal that volatility spillovers from the US to the other markets have become stronger, whereas those from the UK have become weaker. Particularly, in our most recent period from 2004 to 2024, volatility spillovers from the UK to the US that had been previously observed have disappeared. These findings show the existence of the historical transition of volatility spillovers between the three stock markets. We consider that this new evidence is another significant contribution of our study.

Third, the historical constant correlation and DCC values indicate that stock market connectedness has gradually become tighter between the US and Japan and between the UK and Japan, whereas the connectedness between the US and the UK has become weaker in the most recent period. In particular, the DCCs between US and UK stock returns exhibit downward trends toward the end of our most recent period. We consider that this may signify a changing relationship between the US and UK stock markets. Fourth, we also find that our VAR-DCC model incorporating asymmetric spillovers is well estimated, proving that volatility spillovers between the three stock markets are asymmetric. We consider that this implies the effectiveness of incorporating asymmetry in analyzing volatility spillovers in the three international stock markets. Fifth, we also find that the skew-*t* errors incorporated into our quantitative model are effective in our model estimations. We consider that this indicates the effectiveness of incorporating return skewness into the econometric modeling of the three international stock market returns. Finally, in addition to the above, we further present significant and beneficial interpretations and implications; this is an added and valuable contribution of our research.

The rest of the paper is organized as follows. Section 2 explains the data and Section 3 presents our models. Section 4 describes our results, Section 5 provides discussions, and Section 6 summarizes and concludes the paper.

2. Data and research design

This study analyzes the weekly returns of stock price indexes of the US, the UK, and Japan. Specifically, the three indexes this study employs are the S&P 500 for the US, the FTSE 100 for the UK, and the TOPIX for Japan. We obtained the three index price data from Bloomberg. Using the three stock index prices of p_t (prices at time t) and p_{t-1} (prices at time $t-1$), we compute the log-difference percentage returns as $\ln(p_t/p_{t-1}) \times 100$ as in the extant research (e.g., Mensi et al., 2019; Abakah et al., 2020; Tsuji, 2020). To examine the dynamic interactions between the different time-zone markets, we specify the weekly returns for these three stock markets.

Figure 1 plots the price evolution of the S&P 500 for the US (Panel A), the FTSE 100 for the UK (Panel B), and the TOPIX for Japan (Panel C). As shown, before approximately 2000, Japanese stock market returns display different price movements. Figure 2 plots the stock return evolution in the US (Panel A), the UK (Panel B), and Japan (Panel C). From this figure, we recognize that the returns of the three stock markets display different fluctuations. These simple observations suggest the existence of historical changes in the state of the dynamic interactions between the three stock markets. Furthermore, all three stock prices largely dropped during the global financial crisis (GFC) and the outbreak of the COVID-19 pandemic (Figure 1); however, the degrees of the fluctuations of the three stock returns were different during the above times (Figure 2). Moreover, we can see that the European debt crisis (EDC) had a negative impact on UK and Japanese stock prices, whereas the EDC did not have a negative effect on US stock market prices (Figure 1). These graphical analyses also suggest the existence of historical changes in the state of the dynamic linkages between the three stock markets. In line with our research objective to examine the existence of historical transition of return transmission, volatility spillovers, and correlations between the US, UK, and Japanese stock markets, we construct multiple sample periods for the purpose of the analysis.

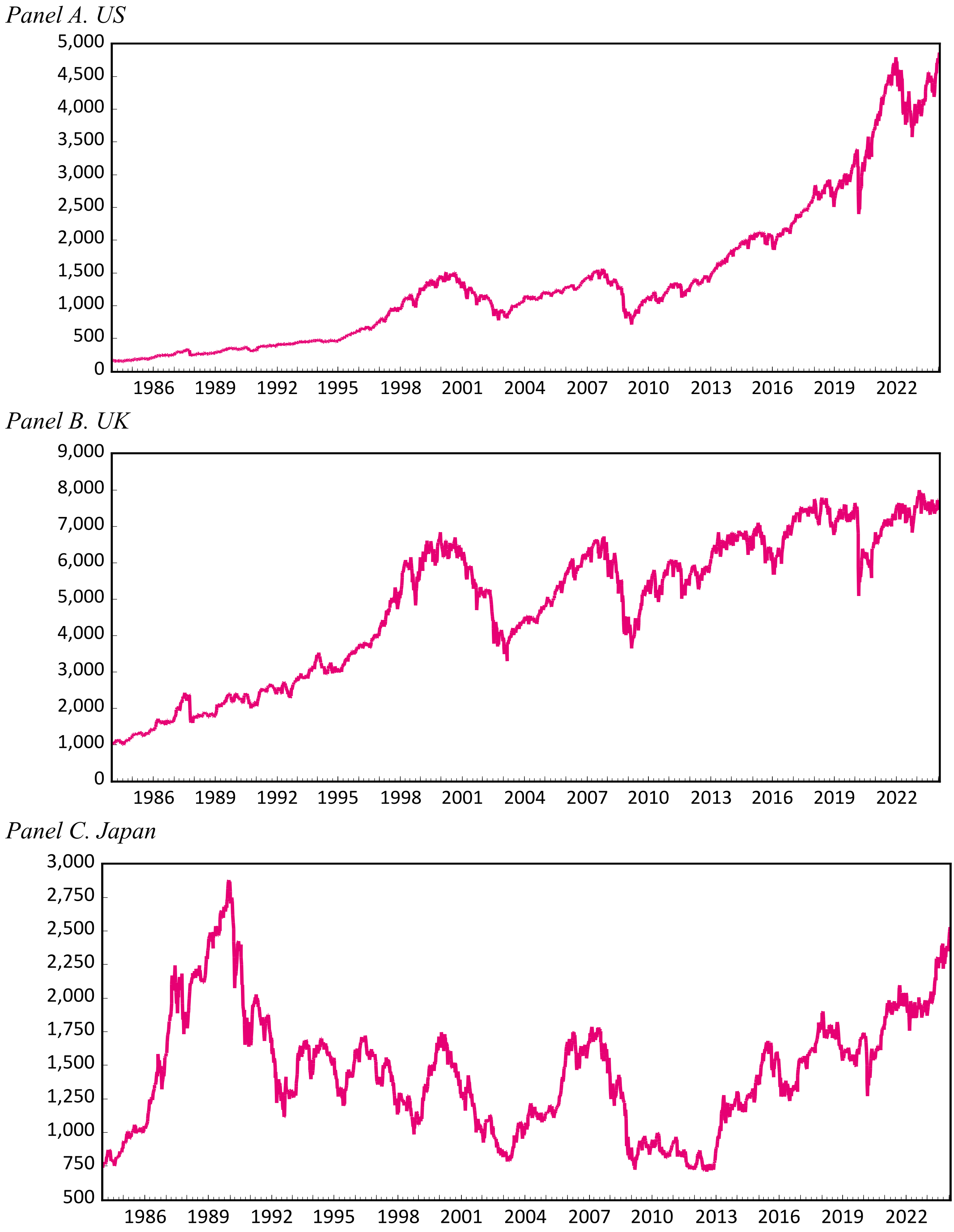


Figure 1. Weekly stock price evolution: January 1984 to January 2024.

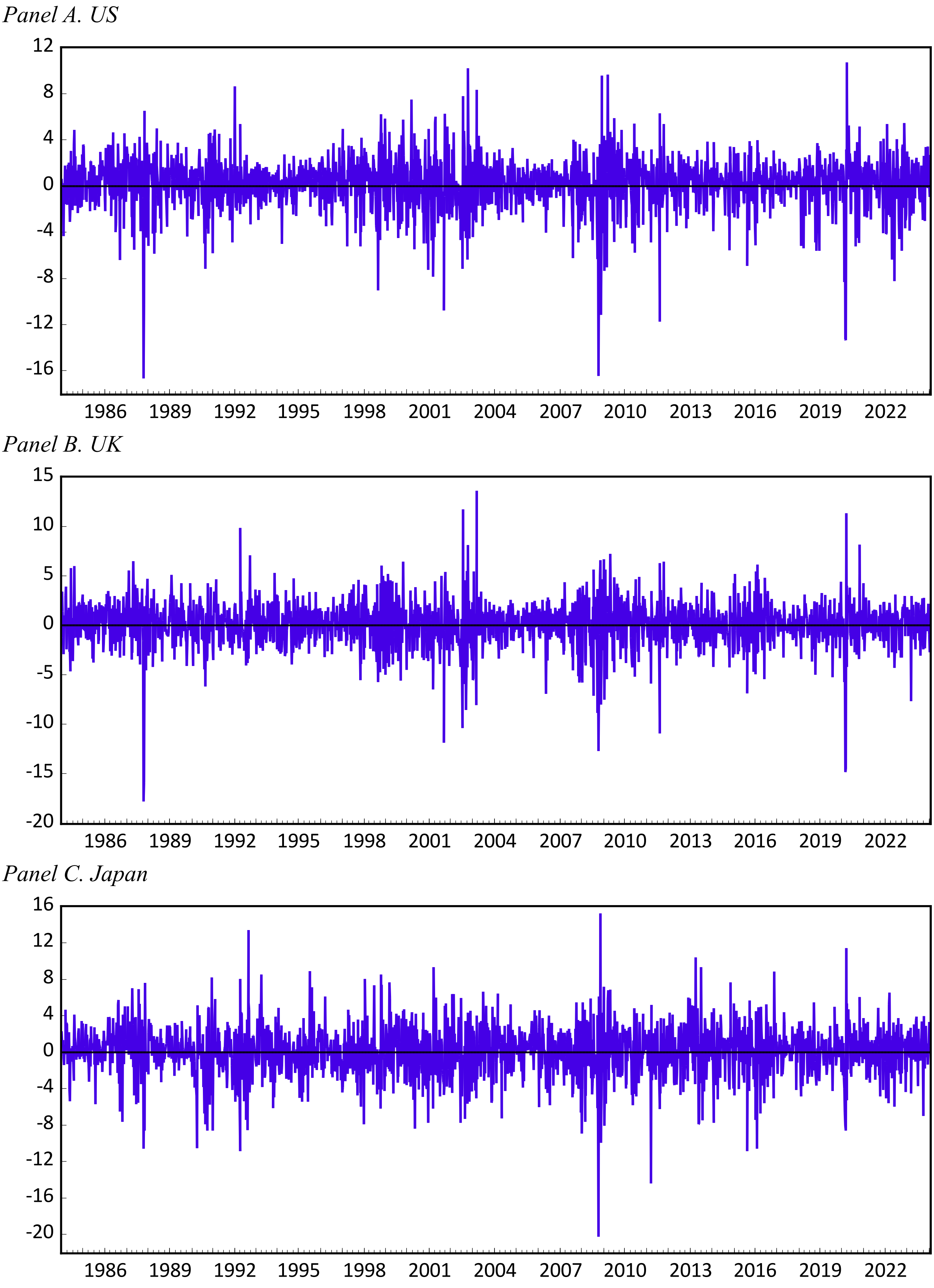


Figure 2. Weekly stock return evolution: January 1984 to January 2024.

Table 1. Summary statistics for the US, UK, and Japanese stock market returns.

Panel A. January 4, 1984, to January 21, 2004			
	US	UK	Japan
Mean	0.195	0.152	0.038
Median	0.366	0.267	0.113
Minimum	−16.663	−17.817	−10.849
Maximum	10.182	13.588	13.406
SD	2.306	2.416	2.778
Skewness	−0.665	−0.636	−0.112
Excess kurtosis	4.619	7.098	1.678
JB	951.936	2142.591	118.090
p-value	0.000	0.000	0.000
ADF	−32.895	−31.316	−31.162
p-value	0.000	0.000	0.000
Panel B. September 5, 1990, to September 22, 2010			
	US	UK	Japan
Mean	0.127	0.097	−0.082
Median	0.275	0.269	0.035
Minimum	−16.452	−12.732	−20.280
Maximum	10.182	13.588	15.229
SD	2.383	2.440	2.997
Skewness	−0.542	−0.242	−0.181
Excess kurtosis	4.457	3.485	3.286
JB	868.077	510.793	450.718
p-value	0.000	0.000	0.000
ADF	−33.216	−33.842	−32.543
p-value	0.000	0.000	0.000
Panel C. June 4, 1997, to May 24, 2017			
	US	UK	Japan
Mean	0.105	0.048	0.005
Median	0.293	0.237	0.207
Minimum	−16.452	−12.732	−20.280
Maximum	10.182	13.588	15.229
SD	2.410	2.510	3.050
Skewness	−0.695	−0.340	−0.404
Excess kurtosis	4.614	3.170	3.231
JB	957.975	433.566	457.488
p-value	0.000	0.000	0.000
ADF	−33.396	−34.685	−33.561
p-value	0.000	0.000	0.000
Panel D. January 28, 2004, to January 24, 2024			
	US	UK	Japan
Mean	0.146	0.052	0.087
Median	0.385	0.204	0.322

Continued on next page

Panel D. January 28, 2004, to January 24, 2024			
	US	UK	Japan
Minimum	−16.452	−14.825	−20.280
Maximum	10.717	11.297	15.229
SD	2.297	2.264	2.839
Skewness	−1.289	−0.944	−0.614
Excess kurtosis	7.314	6.178	4.829
JB	2480.723	1721.766	1024.082
p-value	0.000	0.000	0.000
ADF	−30.831	−32.009	−33.166
p-value	0.000	0.000	0.000

Note: Statistics are for log-difference weekly percentage returns. SD: standard deviation; JB: Jarque-Bera statistic; ADF: augmented Dickey-Fuller test statistic. The returns for the US, UK, and Japanese markets are for the S&P 500, the FTSE 100, and the TOPIX, respectively.

This study analyzes four periods. The oldest period is from January 4, 1984, to January 21, 2004 (hereinafter the "first period"); our second period is from September 5, 1990, to September 22, 2010 (hereinafter the "second period"); our third period is from June 4, 1997, to May 24, 2017 (hereinafter the "third period"); and our most recent period is from January 28, 2004, to January 24, 2024 (hereinafter the "fourth period"). Following the calculation of our weekly returns, the periods yield 989, 990, 990, and 990 observations, respectively. In this study, our focus is on the historical transition of return transmission, volatility spillovers, and DCCs. Therefore, it is important and coherent to construct analyzing sample periods in chronological order as above. Furthermore, by keeping the sample numbers consistent across the above four periods, we can compare the results in a meaningful and statistically sound manner.

In addition, these sample periods are economically different and thus also meaningful to analyze separately. That is, the second period contains the GFC, the third period comprises the GFC and EDC, and the fourth period includes the GFC, EDC, Brexit, the COVID-19 outbreak, and the Russian invasion of Ukraine, whereas the first period does not contain any of the above events. We note that the precise quantitative determination of the transition regime in return transmission and volatility spillovers is not the focus of our current study. However, our careful and thoughtful selection of the four sample periods mentioned above should effectively clarify the historical transition and differences in return transmission, volatility spillovers, and DCCs between the US, UK, and Japanese stock markets.

Table 1 provides descriptive statistics for the three sets of stock market returns for each of the four periods. As shown, all returns exhibit negative values for skewness, with the US stock market returns displaying the largest negative skewness value for each period. Moreover, Table 1 indicates that the skewness of all three returns became more negative during the third and fourth periods (Panels C–D). In addition, the values of excess kurtosis for all the returns are positive, indicating that all the return series have fat tails. Table 1 also shows that Jarque-Bera statistics reject the assumption of normality for all series. These return characteristics suggest the effectiveness of incorporating fat-tailed and skewed distributions when specifying quantitative models for these series. Further, the augmented Dickey–Fuller tests in Table 1 all reject the null hypothesis of a unit root, indicating that all of the return series are stationary.

3. Model

To identify the historical transition of return transmission, volatility spillovers, and DCCs, we apply an extended DCC model. Specifically, we employ the following VAR-skew-t error (ST)-DCC-asymmetric spillover (AS)-MEGARCH (hereinafter, the VAR-ST-DCC-AS-MEGARCH) model:

$$r_{i,t} = \gamma_{i,0} + \sum_{j=1}^{n} \gamma_{i,j}\, r_{j,t-1} + \tau_{i,t}, \text{ for } i = 1,\dots,n, \tag{1}$$

$$\ln(h_{i,t}) = \mu_i + \sum_{j=1}^{n} \xi_{i,j} \left(\frac{|\tau_{j,t-1}|}{\sqrt{h_{j,t-1}}} + \delta_j \frac{\tau_{j,t-1}}{\sqrt{h_{j,t-1}}} \right) + \eta_i \ln(h_{i,t-1}), \text{ for } i = 1,\dots,n. \tag{2}$$

This is a trivariate model extension of the bivariate model of Tsuji (2018). The trivariate version of the VAR-ST-DCC-AS-MEGARCH model is suitable for our analysis because this model can analyze:

1. the time series of the three equities simultaneously,
2. return transmission and volatility spillovers simultaneously,
3. the skewness of stock returns as shown in Table 1,
4. the leverage effect of volatility spillovers often seen in stock returns, and
5. DCCs between the three stock returns simultaneously.

Therefore, using this trivariate model, this study examines return transmission, volatility spillovers, and DCCs between the three stock markets of the US, the UK, and Japan. Hence, in models (1)–(2), we have $i = 1,\dots,n$ and $j = 1,\dots,n$ and n always equals three because our model is trivariate. The remaining notations in models (1)–(2) are as follows:

- $r_{i,t}(r_{j,t-1})$: stock market returns at time t ($t-1$) of the US, UK, or Japan,
- $\gamma_{i,0}$: constant terms of the VAR mean equations,
- $\gamma_{i,j}$: coefficients of the first lags of the VAR mean equations,
- $\tau_{i,t}$: skew-t distribution errors with a shape parameter v and skewness parameters θ_i,
- $h_{i,t}(h_{i,t-1})$: variances of the US, UK, or Japanese stock market returns at time t ($t-1$),
- μ_i: constant terms of the variance equations,
- $\xi_{i,j}$: spillover parameters from series j to i,
- $\frac{|\tau_{j,t-1}|}{\sqrt{h_{j,t-1}}}$: absolute return shocks of series j at time $t-1$,
- δ_j: asymmetry parameters of the return shocks of series j,
- $\frac{\tau_{j,t-1}}{\sqrt{h_{j,t-1}}}$: return shocks of series j at time $t-1$,
- η_i: GARCH-effect parameters.

Note that a negative δ_j associated with a positive $\xi_{i,j}$ indicates asymmetric spillovers from series j to series i. Further, in the models, the skew-t distribution errors $\tau_{i,t}$ have a common shape parameter v and each skewness parameter θ_i; and $\ln\theta_i > 0$ ($\ln\theta_i < 0$) denotes the right (left) skewness of the errors (Bauwens & Laurent, 2005; Tsuji, 2018). The model includes the following DCC component (Engle, 2002; Tsuji, 2018):

$$\mathbf{\Xi}_t = \mathbf{\Gamma}_t \mathbf{\Phi}_t \mathbf{\Gamma}_t. \tag{3}$$

The notations in Equation (3) are as follows.

- $\mathbf{\Xi}_t$: $n \times n$ conditional variance and covariance matrix,
- $\mathbf{\Phi}_t$: conditional correlation matrix,

- $\mathbf{\Gamma}_t$: diagonal matrix with time-varying standard deviations on the diagonal.

In more detail, $\mathbf{\Gamma}_t$ and $\mathbf{\Phi}_t$ are written as:

$$\mathbf{\Gamma}_t = diag\left(\sqrt{h_{1,t}}, \dots, \sqrt{h_{n,t}}\right), \tag{4}$$

$$\mathbf{\Phi}_t = diag\left(\frac{1}{\sqrt{\psi_{1,1,t}}}, \dots, \frac{1}{\sqrt{\psi_{n,n,t}}}\right)\mathbf{\Omega}_t diag\left(\frac{1}{\sqrt{\psi_{1,1,t}}}, \dots, \frac{1}{\sqrt{\psi_{n,n,t}}}\right). \tag{5}$$

In Equation (5), $\mathbf{\Omega}_t$ is an $n \times n$ symmetric positive-definite matrix:

$$\mathbf{\Omega}_t = \begin{bmatrix} \psi_{1,1,t} & \cdots & \psi_{1,n,t} \\ \vdots & \ddots & \vdots \\ \psi_{1,n,t} & \cdots & \psi_{n,n,t} \end{bmatrix}. \tag{6}$$

Further, $\mathbf{\Omega}_t$ is determined with ω and χ being the DCC parameters:

$$\mathbf{\Omega}_t = (1 - \omega - \chi)\overline{\mathbf{\Omega}} + \omega \mathbf{z}_{t-1}\mathbf{z}'_{t-1} + \chi \mathbf{\Omega}_{t-1}. \tag{7}$$

The other notations in Equation (7) are as follows:

- $\overline{\mathbf{\Omega}}$: $n \times n$ unconditional correlation matrix of the standardized return residuals, $z_{i,t}$,
- $\mathbf{z}_{t-1}$: $n \times 1$ matrix of the standardized return residuals at time $t-1$.

Based on this setting, we obtain the DCCs—the time-varying conditional correlation coefficients between series i and j, $\rho_{i,j,t}$, as in Equation (8):

$$\rho_{i,j,t} = \frac{\psi_{i,j,t}}{\sqrt{\psi_{i,i,t}\psi_{j,j,t}}}. \tag{8}$$

To estimate all the parameters of this VAR-ST-DCC-AS-MEGARCH model all at once, we employ the maximum likelihood estimation method using the Broyden-Fletcher-Goldfarb-Shanno algorithm.

4. Results

This section considers the historical transition of return transmission, volatility spillovers, and correlations between the US, UK, and Japanese stock markets by examining the estimation results of our VAR-ST-DCC-AS-MEGARCH models in Tables 2–5. Tables 2–5 provide the estimation results for the first, second, third, and fourth periods, respectively. As shown in Tables 2–5, we can see that our VAR-ST-DCC-AS-MEGARCH models are well estimated.

In addition, we provide the log-likelihood ratio (LR) test results of the model error distributions in Table 6. This table shows that the skew-*t* distribution errors are always superior to the normal or Student-*t* distribution errors, regardless of period, and this demonstrates the effectiveness of incorporating skew-*t* errors into our econometric models for our weekly data analyses.

Table 2. Estimation results of the VAR-ST-DCC-AS-MEGARCH models for the US, UK, and Japan: January 4, 1984, to January 21, 2004.

Panel A. Mean equations				
Coefficients	Estimates	Standard error	t-statistic	p-value
$\gamma_{1,0}$	0.165***	0.045	3.643	0.000
$\gamma_{1,1}$	−0.067**	0.031	−2.204	0.027
$\gamma_{1,2}$	0.042*	0.025	1.650	0.099
$\gamma_{1,3}$	−0.009	0.019	−0.471	0.638
$\gamma_{2,0}$	0.133***	0.034	3.903	0.000
$\gamma_{2,1}$	0.054*	0.028	1.932	0.053
$\gamma_{2,2}$	−0.024	0.028	−0.862	0.388
$\gamma_{2,3}$	−0.026	0.020	−1.305	0.192
$\gamma_{3,0}$	0.041	0.072	0.563	0.573
$\gamma_{3,1}$	0.038	0.043	0.878	0.380
$\gamma_{3,2}$	−0.006	0.042	−0.145	0.885
$\gamma_{3,3}$	0.043	0.030	1.407	0.159
Panel B. Variance equations				
Coefficients	Estimates	Standard error	t-statistic	p-value
μ_1	−0.066*	0.036	−1.847	0.065
μ_2	−0.049	0.051	−0.972	0.331
μ_3	−0.047	0.043	−1.074	0.283
$\xi_{1,1}$	0.120***	0.036	3.382	0.001
$\xi_{1,2}$	0.112***	0.038	2.961	0.003
$\xi_{1,3}$	0.008	0.028	0.295	0.768
$\xi_{2,1}$	−0.017	0.041	−0.420	0.674
$\xi_{2,2}$	0.241***	0.045	5.335	0.000
$\xi_{2,3}$	0.045	0.034	1.309	0.191
$\xi_{3,1}$	−0.014	0.037	−0.396	0.692
$\xi_{3,2}$	0.105***	0.040	2.624	0.009
$\xi_{3,3}$	0.214***	0.037	5.761	0.000
η_1	0.922***	0.025	36.303	0.000
η_2	0.901***	0.037	24.615	0.000
η_3	0.903***	0.024	37.049	0.000
δ_1	−0.548***	0.211	−2.601	0.009
δ_2	−0.463***	0.133	−3.494	0.000
δ_3	−0.427***	0.125	−3.428	0.001
ω	0.006**	0.003	2.132	0.033
χ	0.991***	0.006	164.876	0.000
ν	10.451***	0.863	12.116	0.000
$\ln\theta_1$	−0.238***	0.043	−5.480	0.000
$\ln\theta_2$	−0.033	0.044	−0.750	0.453
$\ln\theta_3$	−0.015	0.043	−0.340	0.734
LL	−6,263.837			

Note: LL denotes the log-likelihood value. ***, **, and * denote 1%, 5%, and 10% significance levels, respectively.

Table 3. Estimation results of the VAR-ST-DCC-AS-MEGARCH model for the US, UK, and Japan: September 5, 1990, to September 22, 2010.

Panel A. Mean equations				
Coefficients	Estimates	Standard error	t-statistic	p-value
$\gamma_{1,0}$	0.088***	0.012	7.398	0.000
$\gamma_{1,1}$	−0.114***	0.024	−4.671	0.000
$\gamma_{1,2}$	0.072***	0.003	21.644	0.000
$\gamma_{1,3}$	−0.042***	0.006	−7.537	0.000
$\gamma_{2,0}$	0.071*	0.043	1.665	0.096
$\gamma_{2,1}$	0.045	0.031	1.459	0.145
$\gamma_{2,2}$	−0.052*	0.028	−1.836	0.066
$\gamma_{2,3}$	−0.044**	0.018	−2.446	0.014
$\gamma_{3,0}$	−0.053	0.073	−0.733	0.463
$\gamma_{3,1}$	0.098***	0.038	2.598	0.009
$\gamma_{3,2}$	−0.032	0.039	−0.813	0.416
$\gamma_{3,3}$	−0.006	0.027	−0.218	0.827
Panel B. Variance equations				
Coefficients	Estimates	Standard error	t-statistic	p-value
μ_1	−0.121***	0.029	−4.242	0.000
μ_2	−0.054**	0.028	−1.960	0.050
μ_3	−0.008	0.039	−0.209	0.834
$\xi_{1,1}$	0.155***	0.031	4.998	0.000
$\xi_{1,2}$	0.070**	0.031	2.260	0.024
$\xi_{1,3}$	0.043*	0.024	1.747	0.081
$\xi_{2,1}$	−0.017	0.030	−0.559	0.576
$\xi_{2,2}$	0.147***	0.031	4.682	0.000
$\xi_{2,3}$	0.044**	0.020	2.133	0.033
$\xi_{3,1}$	−0.017	0.035	−0.489	0.625
$\xi_{3,2}$	0.100***	0.031	3.180	0.001
$\xi_{3,3}$	0.137***	0.031	4.421	0.000
η_1	0.941***	0.012	76.831	0.000
η_2	0.948***	0.011	84.751	0.000
η_3	0.919***	0.018	51.305	0.000
δ_1	−0.421***	0.156	−2.699	0.007
δ_2	−0.889***	0.196	−4.534	0.000
δ_3	−0.541***	0.176	−3.070	0.002
ω	0.011***	0.003	3.950	0.000
χ	0.987***	0.004	244.016	0.000
ν	10.794***	1.038	10.397	0.000
$\ln\theta_1$	−0.286***	0.043	−6.628	0.000
$\ln\theta_2$	−0.072*	0.043	−1.673	0.094
$\ln\theta_3$	−0.016	0.043	−0.380	0.704
LL	−6,156.209			

Note: LL denotes the log-likelihood value. ***, **, and * denote 1%, 5%, and 10% significance levels, respectively.

Table 4. Estimation results of the VAR-ST-DCC-AS-MEGARCH model for the US, UK, and Japan: June 4, 1997, to May 24, 2017.

Panel A. Mean equations				
Coefficients	Estimates	Standard error	t-statistic	p-value
$\gamma_{1,0}$	0.058***	0.003	18.356	0.000
$\gamma_{1,1}$	−0.128***	0.011	−11.711	0.000
$\gamma_{1,2}$	0.100***	0.005	19.373	0.000
$\gamma_{1,3}$	−0.052***	0.001	−66.259	0.000
$\gamma_{2,0}$	−0.030	0.041	−0.728	0.467
$\gamma_{2,1}$	0.046*	0.027	1.704	0.088
$\gamma_{2,2}$	−0.044*	0.023	−1.882	0.060
$\gamma_{2,3}$	−0.060***	0.015	−4.077	0.000
$\gamma_{3,0}$	0.003	0.069	0.041	0.967
$\gamma_{3,1}$	0.183***	0.042	4.303	0.000
$\gamma_{3,2}$	−0.051	0.037	−1.368	0.171
$\gamma_{3,3}$	−0.080***	0.026	−3.072	0.002
Panel B. Variance equations				
Coefficients	Estimates	Standard error	t-statistic	p-value
μ_1	−0.050**	0.022	−2.254	0.024
μ_2	−0.030	0.029	−1.070	0.285
μ_3	0.038	0.051	0.747	0.455
$\xi_{1,1}$	0.141***	0.030	4.685	0.000
$\xi_{1,2}$	0.076**	0.034	2.245	0.025
$\xi_{1,3}$	−0.016	0.027	−0.589	0.556
$\xi_{2,1}$	0.033	0.023	1.474	0.140
$\xi_{2,2}$	0.165***	0.043	3.830	0.000
$\xi_{2,3}$	−0.007	0.032	−0.214	0.831
$\xi_{3,1}$	0.062*	0.032	1.945	0.052
$\xi_{3,2}$	0.073**	0.037	1.958	0.050
$\xi_{3,3}$	0.082**	0.035	2.349	0.019
η_1	0.934***	0.012	75.607	0.000
η_2	0.930***	0.014	65.149	0.000
η_3	0.904***	0.025	35.980	0.000
δ_1	−0.832***	0.183	−4.535	0.000
δ_2	−0.866***	0.231	−3.739	0.000
δ_3	−0.163	0.258	−0.633	0.526
ω	0.013***	0.005	2.678	0.007
χ	0.975***	0.010	101.990	0.000
ν	10.067***	1.475	6.823	0.000
$\ln\theta_1$	−0.405***	0.045	−9.056	0.000
$\ln\theta_2$	−0.082*	0.043	−1.891	0.059
$\ln\theta_3$	−0.042	0.041	−1.021	0.307
LL	−6,043.880			

Note: LL denotes the log-likelihood value. ***, **, and * denote 1%, 5%, and 10% significance levels, respectively.

Table 5. Estimation results of the VAR-ST-DCC-AS-MEGARCH model for the US, UK, and Japan: January 28, 2004, to January 24, 2024.

Panel A. Mean equations				
Coefficients	Estimates	Standard error	t-statistic	p-value
$\gamma_{1,0}$	0.091*	0.050	1.811	0.070
$\gamma_{1,1}$	−0.079**	0.039	−2.039	0.041
$\gamma_{1,2}$	0.051	0.035	1.444	0.149
$\gamma_{1,3}$	−0.046**	0.020	−2.280	0.023
$\gamma_{2,0}$	−0.022	0.053	−0.416	0.678
$\gamma_{2,1}$	0.085**	0.040	2.143	0.032
$\gamma_{2,2}$	−0.053	0.040	−1.320	0.187
$\gamma_{2,3}$	−0.061**	0.024	−2.535	0.011
$\gamma_{3,0}$	0.070	0.067	1.045	0.296
$\gamma_{3,1}$	0.191***	0.052	3.693	0.000
$\gamma_{3,2}$	−0.047	0.053	−0.891	0.373
$\gamma_{3,3}$	−0.119***	0.036	−3.310	0.001
Panel B. Variance equations				
Coefficients	Estimates	Standard error	t-statistic	p-value
μ_1	−0.076**	0.031	−2.468	0.014
μ_2	−0.053*	0.029	−1.822	0.068
μ_3	−0.030	0.040	−0.739	0.460
$\xi_{1,1}$	0.218***	0.033	6.521	0.000
$\xi_{1,2}$	0.029	0.020	1.489	0.136
$\xi_{1,3}$	−0.009	0.030	−0.305	0.760
$\xi_{2,1}$	0.075***	0.025	2.944	0.003
$\xi_{2,2}$	0.086**	0.035	2.445	0.015
$\xi_{2,3}$	0.027	0.030	0.884	0.376
$\xi_{3,1}$	0.055*	0.032	1.721	0.085
$\xi_{3,2}$	0.052*	0.030	1.718	0.086
$\xi_{3,3}$	0.130***	0.040	3.220	0.001
η_1	0.934***	0.012	75.831	0.000
η_2	0.944***	0.013	73.695	0.000
η_3	0.926***	0.022	43.023	0.000
δ_1	−0.559***	0.142	−3.937	0.000
δ_2	−1.352**	0.656	−2.060	0.039
δ_3	0.081	0.219	0.371	0.711
ω	0.018*	0.011	1.648	0.099
χ	0.967***	0.023	41.755	0.000
ν	7.792***	0.951	8.197	0.000
$\ln\theta_1$	−0.511***	0.047	−10.993	0.000
$\ln\theta_2$	−0.059	0.046	−1.280	0.201
$\ln\theta_3$	−0.034	0.043	−0.792	0.429
LL	−5,757.508			

Note: LL denotes the log-likelihood value. ***, **, and * denote 1%, 5%, and 10% significance levels, respectively.

Table 6. LR test results for model error distributions.

Panel A. January 4, 1984, to January 21, 2004		
	Normal vs. Student-t	Student-t vs. Skew-t
Test statistic	89.945***	24.992***
p-value	0.000	0.000
Panel B. September 5, 1990, to September 22, 2010		
	Normal vs. Student-t	Student-t vs. Skew-t
Test statistic	62.373***	37.651***
p-value	0.000	0.000
Panel C. June 4, 1997, to May 24, 2017		
	Normal vs. Student-t	Student-t vs. Skew-t
Test statistic	74.062***	81.210***
p-value	0.000	0.000
Panel D. January 28, 2004, to January 24, 2024		
	Normal vs. Student-t	Student-t vs. Skew-t
Test statistic	121.963***	128.350***
p-value	0.000	0.000

Note: *** denotes rejection of the null hypothesis at the 1% significance level. The test statistic follows a χ^2 distribution. The null hypothesis in "Normal vs. Student-*t*" is that the normal distribution errors are superior to the Student-*t* distribution errors; the null hypothesis in "Student-*t* vs. Skew-*t*" is that the Student-*t* distribution errors are superior to the skew-*t* distribution errors.

Table 7. Summary of the historical transition of return transmission and volatility spillovers between the US, UK, and Japanese stock markets.

Panel A. Return transmission			
A–1. January 4, 1984, to January 21, 2004			
	Receiver		
Transmitter	US	UK	Japan
US	–	YES	NO
UK	YES	–	NO
Japan	NO	NO	–
A–2. September 5, 1990, to September 22, 2010			
	Receiver		
Transmitter	US	UK	Japan
US	–	NO	YES
UK	YES	–	NO
Japan	NO	NO	–
A–3. June 4, 1997, to May 24, 2017			
	Receiver		
Transmitter	US	UK	Japan
US	–	YES	YES
UK	YES	–	NO
Japan	NO	NO	–

Continued on next page

A–4. January 28, 2004, to January 24, 2024			
	Receiver		
Transmitter	US	UK	Japan
US	–	YES	YES
UK	NO	–	NO
Japan	NO	NO	–
Panel B. Volatility spillover			
B–1. January 4, 1984, to January 21, 2004			
	Receiver		
Transmitter	US	UK	Japan
US	–	NO	NO
UK	YES	–	YES
Japan	NO	NO	–
B–2. September 5, 1990, to September 22, 2010			
	Receiver		
Transmitter	US	UK	Japan
US	–	NO	NO
UK	YES	–	YES
Japan	YES	YES	–
B–3. June 4, 1997, to May 24, 2017			
	Receiver		
Transmitter	US	UK	Japan
US	–	NO	YES
UK	YES	–	YES
Japan	NO	NO	–
B–4. January 28, 2004, to January 24, 2024			
	Receiver		
Transmitter	US	UK	Japan
US	–	YES	YES
UK	NO	–	YES
Japan	NO	NO	–

Note: YES denotes the existence of return transmission (volatility spillovers) from the transmitter to the receiver; NO denotes no return transmission (volatility spillover) from the transmitter to the receiver.

4.1. Return transmission

We first examine the historical transition of return transmission between the US, UK, and Japanese stock markets. First, Panel A in Table 2 shows that the return transmission parameters $\gamma_{1,2}$ and $\gamma_{2,1}$ are statistically significant. This indicates that, in the first period, there was return transmission from the US to the UK and from the UK to the US. Next, Panel A in Table 3 shows that the return transmission parameters $\gamma_{1,2}$ and $\gamma_{3,1}$ are statistically significant. Hence, in the second period, there was return transmission from the UK to the US and from the US to Japan.

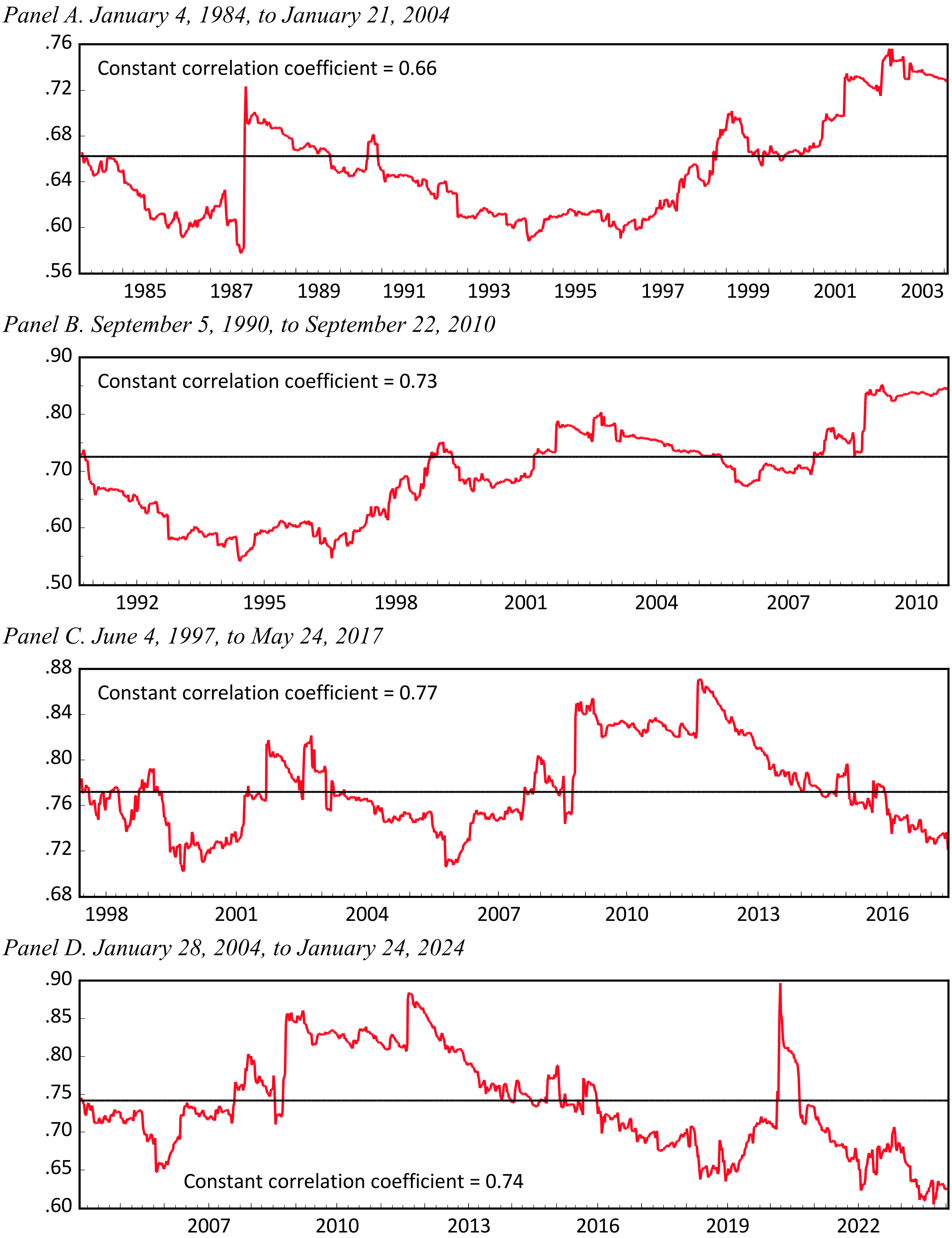
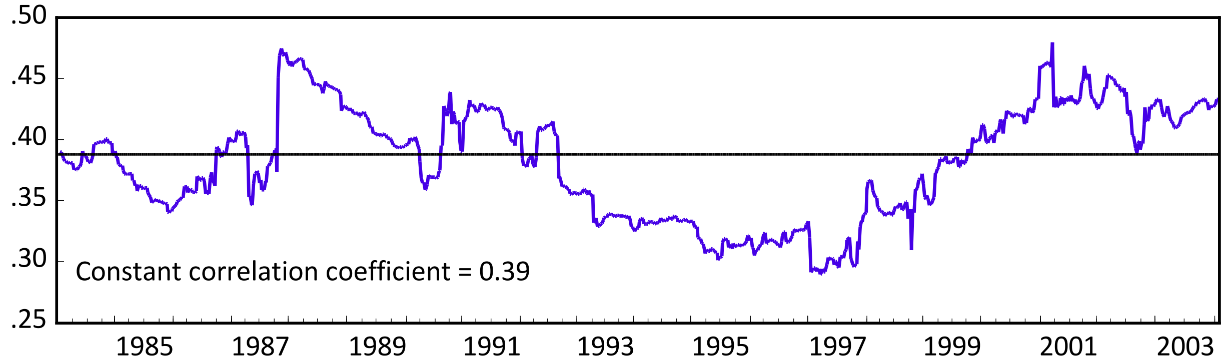
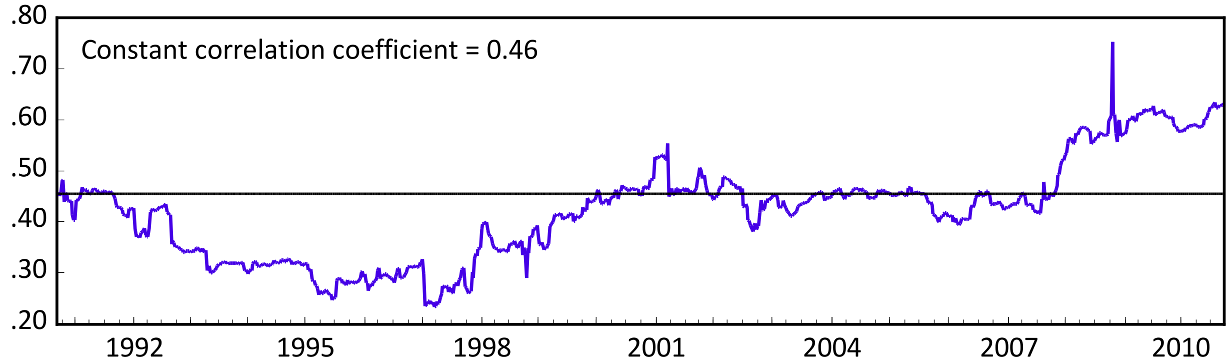


Figure 3. Dynamic conditional correlations between the US and UK stock markets.

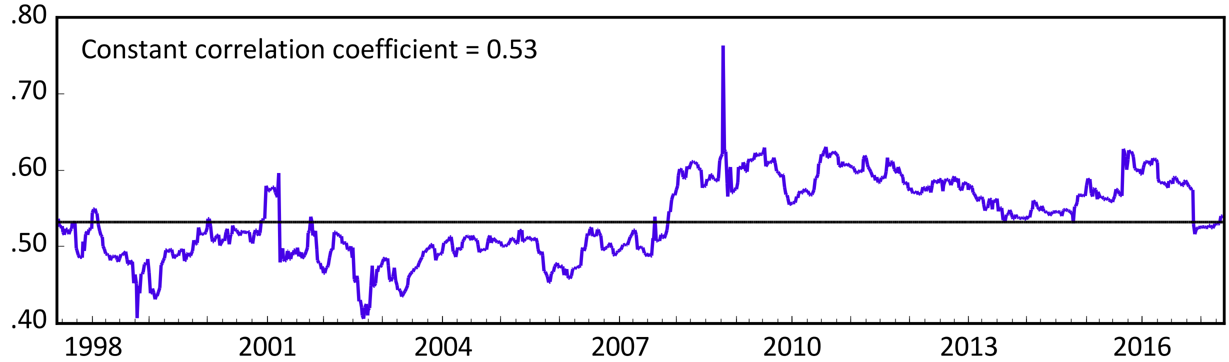
Panel A. January 4, 1984, to January 21, 2004



Panel B. September 5, 1990, to September 22, 2010



Panel C. June 4, 1997, to May 24, 2017



Panel D. January 28, 2004, to January 24, 2024

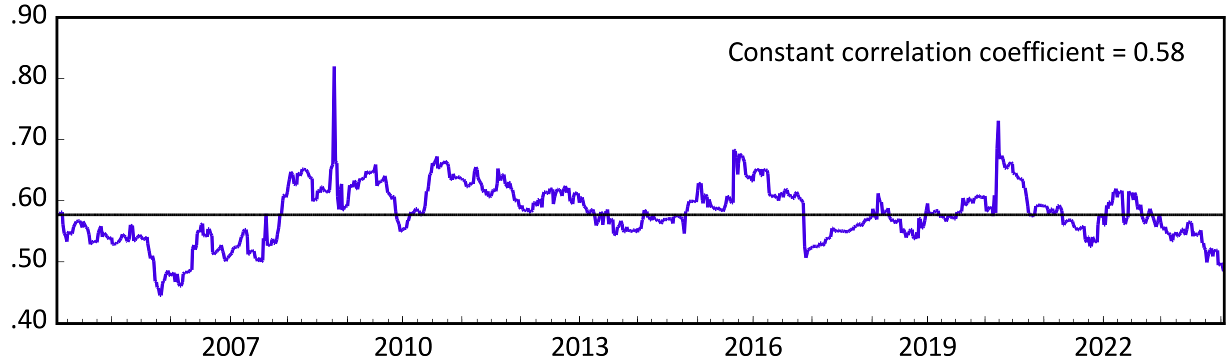


Figure 4. Dynamic conditional correlations between the US and Japanese stock markets.

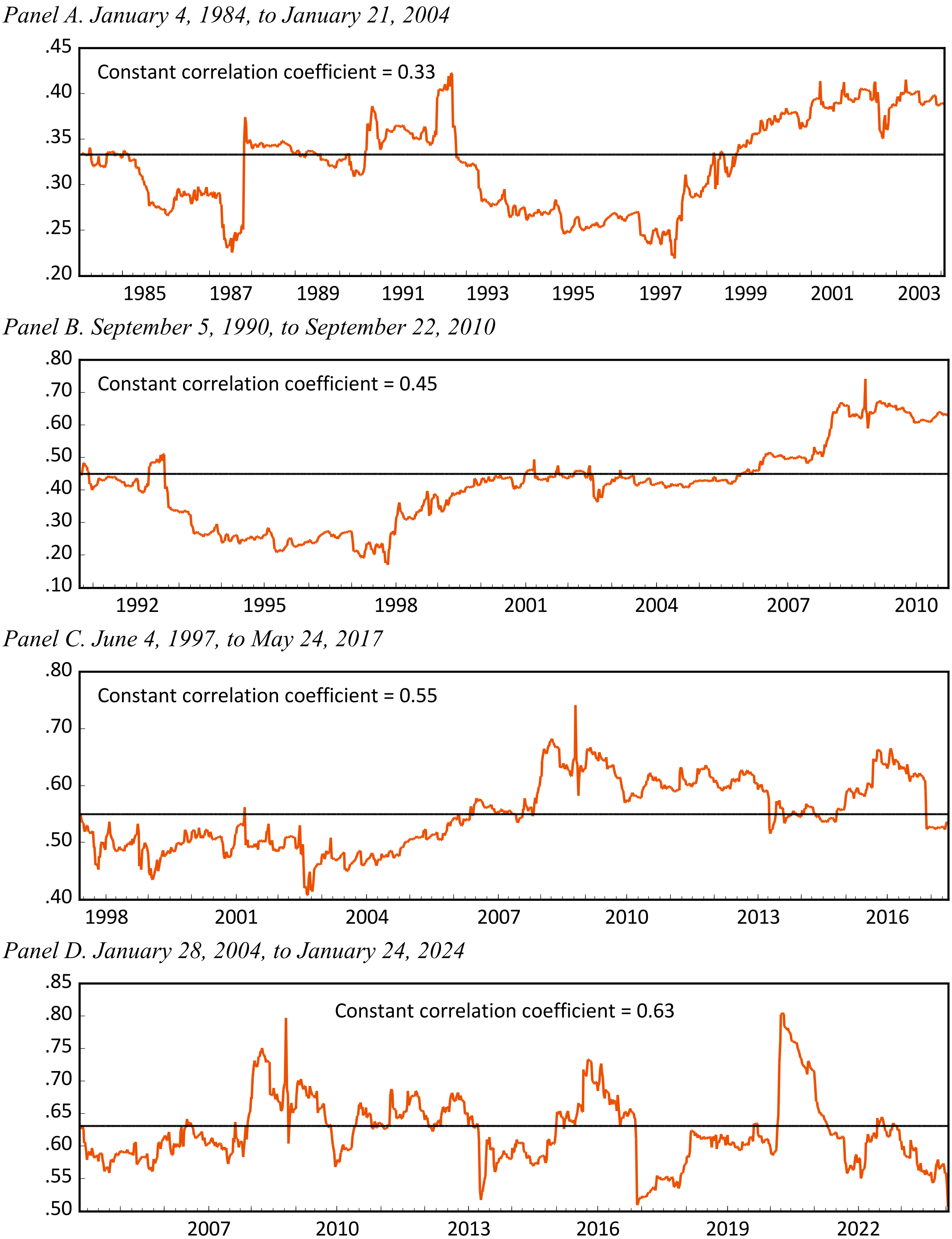


Figure 5. Dynamic conditional correlations between the UK and Japanese stock markets.

Table 8. Variances, covariances, and correlations for the US, UK, and Japanese stock market returns.

	US	UK	Japan
Panel A. January 4, 1984, to January 21, 2004			
	US	UK	Japan
US	5.314	0.662	0.388
UK	3.686	5.830	0.333
Japan	2.483	2.233	7.708
Panel B. September 5, 1990, to September 22, 2010			
	US	UK	Japan
US	5.675	0.725	0.455
UK	4.212	5.949	0.450
Japan	3.249	3.288	8.975
Panel C. June 4, 1997, to May 24, 2017			
	US	UK	Japan
US	5.801	0.772	0.532
UK	4.666	6.294	0.549
Japan	3.908	4.199	9.296
Panel D. January 28, 2004, to January 24, 2024			
	US	UK	Japan
US	5.269	0.742	0.577
UK	3.854	5.120	0.631
Japan	3.757	4.052	8.049

Note: The six values on and below the diagonal running from upper left to lower right are for the variance-covariance matrix; the three values above the diagonal are for the correlation matrix. The returns for the US, UK, and Japan are for the S&P 500, the FTSE 100, and the TOPIX, respectively.

Third, Panel A in Table 4 shows that the return transmission parameters $\gamma_{1,2}$, $\gamma_{2,1}$, and $\gamma_{3,1}$ are statistically significant, indicating that, in the third period, there was return transmission from the US to the UK and Japan, and from the UK to the US. Finally, Panel A in Table 5 demonstrates that the return transmission parameters $\gamma_{2,1}$ and $\gamma_{3,1}$ are statistically significant. Thus, this shows that, in the fourth period, there was return transmission from the US to the UK and Japan.

To make it easier to understand the overall situation regarding return transmission between the three stock markets, Panel A in Table 7 provides summary results. As we can see, return transmission became stronger from the US to the other markets but weaker from the UK to the other markets, and return transmission from Japan is not evident in any period. It is notable that in the fourth period, there was return transmission from the US to both the UK and Japan, but we cannot discern any return transmission from the UK to either the US or Japan. This suggests that the strength of the international effects of the US and UK stock markets has recently shifted.

4.2. Volatility spillovers

We next examine the historical transition of volatility spillovers between the US, UK, and Japanese stock markets. First, Panel B in Table 2 shows that the volatility spillover parameters $\xi_{1,2}$ and $\xi_{3,2}$ are statistically significant. That is, during the first period, there were volatility spillovers from the UK to both the US and Japan. Second, Panel B in Table 3 indicates that the volatility spillover parameters $\xi_{1,2}$, $\xi_{3,2}$, $\xi_{1,3}$, and $\xi_{2,3}$ are also statistically significant. This indicates that during the second period, there were volatility spillovers from the UK to both the US and Japan, and from Japan to both the US and the UK.

Third, Panel B in Table 4 shows that the volatility spillover parameters $\xi_{1,2}$, $\xi_{3,1}$, and $\xi_{3,2}$ are statistically significant, meaning that, during the third period, there were volatility spillovers from the US to Japan and from the UK to both the US and Japan. Finally, Panel B in Table 5 identifies that the volatility spillover parameters $\xi_{2,1}$, $\xi_{3,1}$, and $\xi_{3,2}$ are statistically significant. These results show that, during the fourth period, there were volatility spillovers from the US to the UK and Japan, and from the UK to only Japan.

To make it easier to appreciate the overall situation regarding volatility spillovers, we provide summary results in Panel B of Table 7. From this panel, we can see that volatility spillovers from the US stock market have become gradually stronger, whereas volatility spillovers from Japan are evident only during the second period. It should be noted that as Panel B–4 in Table 7 indicates, during the fourth period, volatility spillovers from the UK to the US previously observed until then have disappeared.

We emphasize that all the statistically significant spillovers above are always associated with statistically significant negative parameters for δ_j. This means that all these spillovers are asymmetric, demonstrating the importance of incorporating asymmetric spillovers into our quantitative models for our weekly data analyses.

4.3. DCCs

We finally examine the correlations between the US, UK, and Japanese stock markets. First, Table 8 shows the constant variances, covariances, and correlations between the US, UK, and Japanese stock market returns for our four periods. The constant correlation values in Table 8 indicate that, from the first to the fourth period, the correlations became gradually higher between the US and Japan and between the UK and Japan, whereas the correlation between the US and the UK became lower during the fourth period, although gradually higher from the first to the third period.

In addition, we also plot the DCCs between the US, UK, and Japanese stock markets obtained from our VAR-ST-DCC-AS-MEGARCH model in Figures 3–5. These figures indicate that, whereas the DCCs are time-varying, they also exhibit a similar tendency. That is, the correlations became gradually higher between the US and Japan and between the UK and Japan, whereas those between the US and the UK became lower in the fourth period following their previous gradual increases.

We further note that Panel D in Figure 3 indicates that around the end of the fourth period, the DCCs between the US and UK stock returns displayed downward trends before and after a jump associated with the COVID-19 pandemic shock. This strengthened interlinkage at the time of the COVID-19 outbreak is consistent with the findings of such existing studies as Akyildirim et al. (2022), Samitas et al. (2022b), Goodell et al. (2023), and Papathanasiou et al. (2023).

Therefore, we emphasize that for the US and UK stock markets, we can observe signs of their linkage shifts in the DCC evolution towards the end of the fourth period. We believe these shifts are associated with Brexit in 2020 and the effects of the COVID-19 pandemic that emerged in 2020.

5. Discussion

In this section, we discuss how this study differs from other studies, and attempt to derive any implications for academicians and industry practitioners. In addition, we will discuss and interpret the key findings of this study. We believe that through this discussion, the contributions of this study will become much clearer.

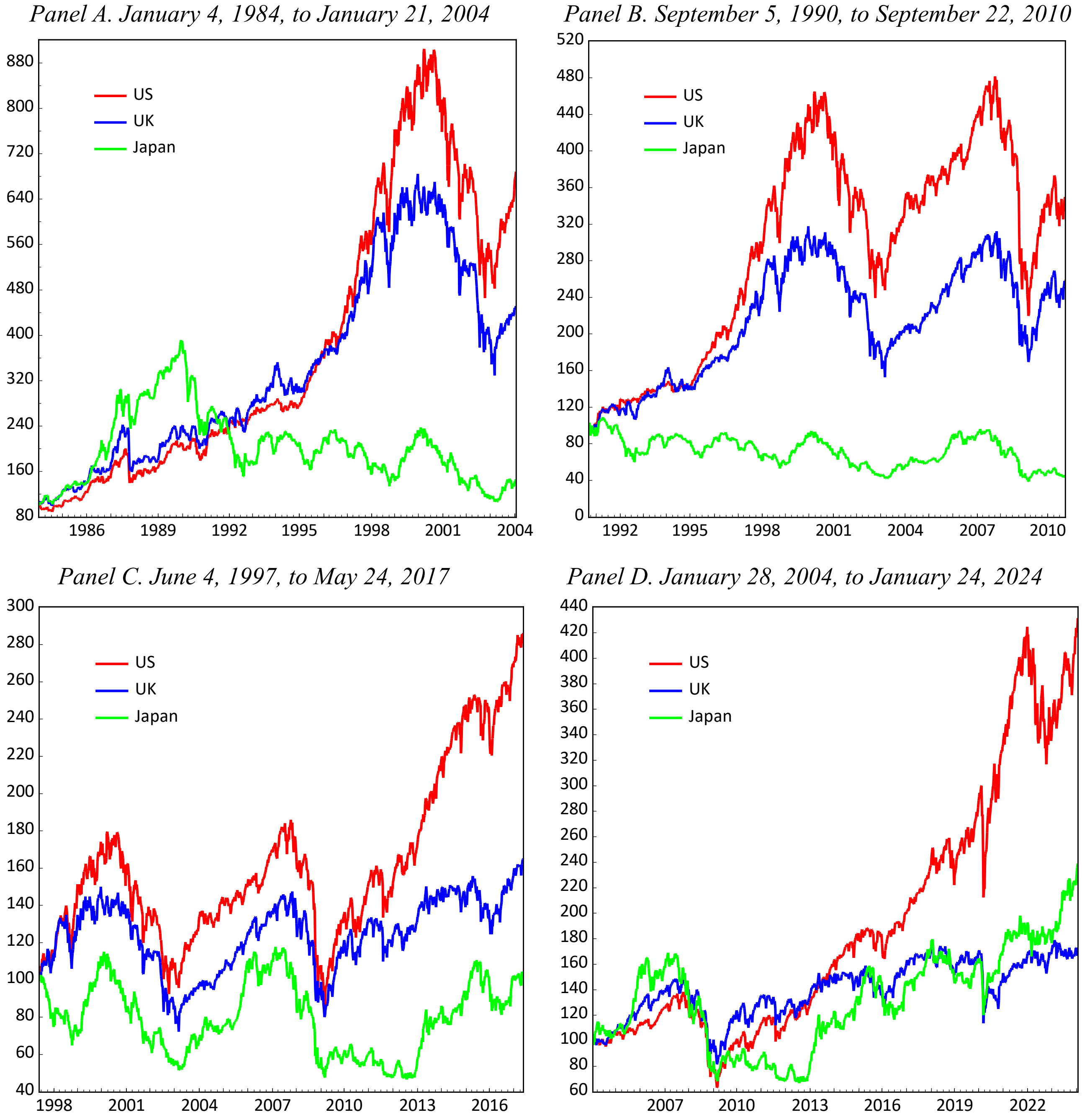


Figure 6. Adjusted stock price evolution: January 1984 to January 2024.

5.1. Uniqueness of this study

We first discuss the uniqueness of this study. The differences between this study and other studies are as follows. First, this study used weekly sample data to accurately capture the dynamic interactions between the countries that have significant time differences. Most other recent studies have used daily samples (e.g., Liang et al., 2020; So et al., 2021; Asadi et al., 2022), but such an approach is not appropriate when there are significant time differences. In contrast, by analyzing weekly time-series data, we were able to properly capture the return transmission, spillover effects, and DCCs especially between the US and Japan, which have significant time differences.

Second, this study used four sample periods to appropriately capture the historical changes in the dynamic interactions between the US, the UK, and Japan, and this historical transition of return transmission, volatility spillovers, and DCCs is a new perspective suggested in this study. Other recent studies have mostly used a single sample period (e.g., Sadorsky, 2012; Ji et al., 2019; Liang et al., 2020), but such an approach is not appropriate for analyzing the historical changes in financial market dynamic interactions. In contrast, by analyzing four economically different sample periods, this study was able to properly capture the historical transition of the return transmission, spillover effects, and DCCs between the US, the UK, and Japan.

The third point pertains to our model, the VAR-ST-DCC-AS-MEGARCH model. The previous studies by Tsuji (2018, 2020) have shown the effectiveness of this model using daily sector stock index data and its bivariate version. In contrast, our current study has demonstrated the effectiveness of the model using weekly overall stock market index data and its trivariate version. Therefore, we believe that the empirical evidence for the effectiveness of the VAR-ST-DCC-AS-MEGARCH model from our current study offers an additional contribution. The fourth point concerns the empirical results. Some previous studies have shown that the spillover effect of the US is significant (e.g., Asadi et al., 2022; Tsuji, 2020). However, to our knowledge, no previous studies have provided statistical evidence indicating that the return transmission and spillover effects of the UK have decreased in recent years.

Overall, the uniqueness of this paper lies in its provision of a fresh perspective: the historical transition of return transmission, volatility spillovers, and DCCs. With this in mind, our current study analyzed the highly significant issue of international stock market nexuses. We believe that this new perspective sets our study apart from the other studies, and our tests of this new perspective fill a research gap left by existing studies.

5.2. Interpretations

Next, we will discuss the interpretations of our main results. As we showed, our main findings in this study are the weakened role of the UK stock market and the stronger role of the US stock market. To show the soundness of the results derived from our analyses and interpret the findings, we further provide the adjusted price evolution of the three international stock markets—S&P 500 for the US, the FTSE 100 for the UK, and the TOPIX for Japan—for our four sample periods in Figure 6. Specifically, Panels A–D display the time series of the adjusted prices of the three stock indexes. The prices at the beginning of each sample period are adjusted to 100 in our first, second, third, and fourth periods.

These graphical analyses are very simple but highly informative in considering the relations and strength of the three international stock markets. Although all four graphs are very useful for understanding the historical transition of the role and strength of the three markets, the most notable is the price evolution comparison in the fourth period shown in Panel D. That is, as shown in Panel D, since around 2013, the UK stock market has consistently underperformed compared with the US stock market. We believe that this is a result of the EDC, as the EDC had a significant impact on Europe, while it did not have a major effect on the US. Afterward, since around 2020, the UK stock market has underperformed compared with the Japanese stock market. We consider that this is due to the effects of both the COVID-19 outbreak in early 2020 and the somewhat closed-door policy of Brexit also in early 2020. We also believe that the COVID-19 outbreak led to deglobalization and the unwinding of international stock market integration. We thus interpret that both events may accelerate the isolation of the UK in international stock markets. In summary, due to the effects of EDC, the COVID-19 outbreak, and Brexit, the influence of the UK stock market has recently declined, as our results of the historical transition of return transmission, volatility spillovers, and DCCs have demonstrated.

We also emphasize that as this highly effective graphical analysis indicates, our careful selection and construction of the four sample periods in chronological order, while maintaining consistent sample numbers across all four periods, are appropriate for inspecting the historical transition of return transmission, volatility spillovers, and DCCs. Therefore, we consider that our main findings regarding the weakened role of the UK stock market and the stronger role of the US stock market in the recent period, which were derived from our four sample period analyses, are statistically sound and empirically robust.

5.3. Implications

We will now delve deeper into the implications of our study. The implications of the weakening relationship between the US and UK stock markets derived from this study suggest that risk diversification and hedging effects for both countries' equities will become higher than before. We consider that this is beneficial for portfolio managers, strategists, and other practitioners involved in investments and asset management.

Furthermore, as we demonstrated in Figure 3, around the end of our fourth period, the DCCs between the US and UK stock returns exhibited downward trends both before and after a spike associated with the COVID-19 pandemic shock. The observation that the correlation temporarily increased at the time of the COVID-19 outbreak, but then weakened again, provides valuable and new insights. Therefore, this finding also has significant implications for future academic research on market integration and connectedness.

6. Contributions and conclusions

This study investigated the historical transition of return transmission, volatility spillovers, and correlations between the US, UK, and Japanese stock markets by applying the VAR-ST-DCC-AS-MEGARCH model. As a result of our rigorous quantitative analysis with a particular focus on the recent state, we derived the following significant findings. We also emphasize that, in this study, we carefully constructed the four analyzing sample periods in chronological order, while keeping the sample numbers consistent across all four periods. Therefore, we consider that the following findings derived from our meticulous analyses are statistically sound and reliable.

- First, our analyses clarified that return transmission from the US to the other markets became stronger. Moreover, it is notable that in our most recent period from 2004 to 2024, and in contrast to the US, no return transmission from the UK to the other markets can be observed. This implies that the strength of the international effects of the US and UK stock markets may have recently shifted. This evidence is significant because it demonstrates the existence of a historical transition of stock return transmission between the US, the UK, and Japan; thus, this new evidence is a significant contribution of this study.
- Second, our examinations revealed that volatility spillovers from the US to the other markets became stronger whereas those from the UK to the other markets became weaker. Particularly in our most recent period from 2004 to 2024, the previously observed volatility spillovers from the UK to the US disappeared. This is important because it also shows the existence of the historical

transition of volatility spillovers between the US, the UK, and Japan, and therefore, this new evidence also demonstrates a significant contribution of this study.

- Third, our investigations of the historical constant correlation and DCC values also clarified that stock market connectedness has become gradually tighter between the US and Japan and between the UK and Japan, whereas that between the US and the UK became weaker in the most recent period. We also revealed that the DCCs between the US and UK stock returns particularly showed downward trends toward the end of the most recent period. We consider that this new evidence is also significant as it may signify a changing relationship between the US and UK stock markets.
- Fourth, our VAR-DCC model incorporating asymmetric spillovers is well estimated for the US, UK, and Japanese stock returns. This shows that volatility spillovers between the three stock markets are asymmetric, implying the effectiveness of incorporating asymmetry in investigating volatility spillovers in the three international stock markets. We note that the previous studies by Tsuji (2018, 2020) have shown the effectiveness of the asymmetry in this model using daily sector stock index data and its bivariate version. In contrast, our current study has demonstrated the effectiveness of the asymmetry in this model using weekly overall stock market index data and its trivariate version. Therefore, we believe that the empirical evidence showing the effectiveness of the asymmetry in the VAR-ST-DCC-AS-MEGARCH model from our current study is an additional contribution to the body of literature and is particularly interesting from a quantitative methodological viewpoint.
- Fifth, our LR tests showed that the skew-*t* errors incorporated into our quantitative model were effective in estimating the dynamic linkages between the three stock markets. Our analyses also suggested that the skewness of stock returns has become gradually stronger, indicating the increasing effectiveness of incorporating return skewness into econometric modeling of international stock returns as in our current study. We emphasize that our present study has evidenced the effectiveness of the incorporated skewness in the VAR-ST-DCC-AS-MEGARCH model by using different data and a different version of the model than those used in Tsuji (2018, 2020). Hence, this evidence is also an additional contribution to existing research and of great benefit from the viewpoint of quantitative modeling.
- Sixth, in addition to the aforementioned points, we have further derived and presented significant and beneficial interpretations and implications through discussions. This is another novel contribution of our work. These interpretations, implications, and our new perspective of the historical transition of return transmission, volatility spillovers, and DCCs should be highly meaningful not only for academic researchers but also for industry practitioners.

The quantitative analyses performed in this study have uncovered the historical transition in return transmission, volatility spillovers, and DCCs between the US, UK, and Japanese stock markets. We consider that these new findings between the three major markets from our analysis are insightful for the fields of both economics and finance because the findings prove our novel perspective on the shifting linkages between the international stock markets. We therefore trust that the evidence, along with the rich interpretations and implications derived from our current study, will significantly contribute to the existing body of literature and future quantitative research in finance and economics.

Use of AI tools declaration

The author declares he has not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

The author declares no conflicts of interest in this paper.

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