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KOMATSUBARA Tadaaki
Ibbotson Associates Japan, Inc.

OKIMOTO Tatsuyoshi
RIETI

TATSUMI Ken-ichi
Gakushuin University

RIETI
Research Institute of Economy, Trade & Industry, IAA

The Research Institute of Economy, Trade and Industry
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Dynamics of Integration in East Asian Equity Markets*

KOMATSUBARA Tadaaki *
Ibbotson Associates Japan, Inc.

OKIMOTO Tatsuyoshi†
Crawford School of Public Policy, Australian National University
Research Institute of Economy, Trade and Industry (RIETI)

and

TATSUMI Ken-ichi‡
Faculty of Economics, Gakushuin University

Abstract

This paper investigates the dynamics of integration in East Asian equity markets between 1995 and 2013 using a smooth-transition correlation GARCH model. Our results show that East Asian equity market integration among China and other countries has increased significantly since 2007, whereas that among other East Asian equity markets excluding China increased significantly in an earlier period from 1999 to 2001. Additionally, we find that increasing integration has been mostly caused by correlation increases in after-trading hours. These results suggest that stock prices in East Asia are sensitive to Europe and U.S. stocks because Europe and U.S. investors were actively investing in East Asian stocks. Indeed, the periods reflect striking increases in integration that correspond approximately to the start of intensive Europe and U.S. investment activity in East Asian stock markets.

Keywords: Stock market linkages, Financial integration, Smooth transition model, Diversification effect

JEL classification: C32; G15

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1. Introduction

The dynamics of international integration in global equity markets plays a crucial role in international asset allocation and risk management. For instance, the weight of an asset in a portfolio and the variance of portfolio return based on the mean-variance approach of modern portfolio theory depend on the correlation of returns among assets.[1] The dynamics of international integration in global equity markets also perform a key function in the estimation of risk measures such as value at risk (VaR) and expected shortfall (ES). Therefore, it is important for empirical finance to analyze the dynamics of international integration in global equity markets. Although some studies examine the dynamics of international integration in global equity markets, there are few similar studies on East Asia. Therefore, we investigate international integration dynamics in East Asian equity markets.

For an investigation of international integration in global equity markets, it is important to recognize that integration is likely to fluctuate in the short term as well as the long term. For example, a shock in a market in a country has been more easily transmitted to other countries' markets since the mid-1990s because of the development of IT and the real-time spread of information. Consequently, it is highly possible that global equity markets have tended to comove to a greater extent in recent years. Additionally, international equity market integration is also likely to fluctuate in conjunction with market uncertainty and investor risk tolerance. Moreover, there may be possible fluctuations in international equity market integration due to financial crises such as the collapse of Lehman Brothers in 2008.

On the other hand, financial market integration has advanced. For instance, Lane and Milesi-Ferretti (2007) note that international financial integration among industrial countries progressed gradually in the 1970s and 1980s and then accelerated in the mid-1990s. The integration of financial markets is also affected by an increase in international macroeconomic policy coordination, the expansion of free-trade, intensification of international economic competition, and the development of the world transportation system. Because these factors have a short and long-term impact on financial market integration, it is important to capture the time variation of international equity market integration. However, capturing all the aspects of complicated time-varying market integration is complex. Therefore, a number of analyses have focused on a specific aspect. This paper focuses on the long-run trend of East Asian equity market integration.

A number of previous studies examine the long-run trends in international equity market integration. For instance, Longin and Solnik (1995) study whether there is a positive trend in the international correlation among the US and six major countries' equity markets using a multivariate GARCH model that has a linear trend in correlation. The authors document significant positive trends in international correlations for four pairs among six pairs with a 0.36 increase on average in

[1] Market integration is measured by correlations in this paper. Both terms are used in interchangeably.

the correlation across international equity markets between 1960 and 1990.[2] However, an assumption of a linear trend in correlation is problematic, since correlation would increase at a constant rate and become larger than one eventually. Berben and Jansen (2005) propose a novel bivariate GARCH model for equity returns with a smoothly time-varying correlation to fix such problems and flexibly investigate transitions in correlation among international equity returns. They find that correlations among the German, UK, and US stock markets increased significantly, whereas Japanese correlations with other countries have remained the same by employing the smooth transition correlation (STC) model.

In contrast, Bekaert, Hodrick, and Zhang (2009) report no evidence of significant positive trends in international equity market integration, excluding the European equity market, based on their APT (Arbitrage Pricing Theory) model with both international factors constructed from international capital markets and regional factors constructed from capital markets in specific regions.

Recently, Christoffersen, Errunza, Jacobs, and Langlois (2012) propose a new dynamic conditional copula correlation model to capture general dependence rather than correlation. Using this model, they analyze the long-run trends of equity market integration in developed and emerging countries and find that integration in the equity markets in developed countries has increased significantly, whereas there is only a limited increase in equity market integration in emerging countries. Finally, Okimoto (2014) extends the STC model to a more general model using a copula to examine the asymmetric long-run trend of integration in major international equity markets. The author demonstrates that international equity market integration has been increasing, but there is some difference in increasing trends between the upper tail and lower tail of international stock returns.

As stated above, a number of preceding studies analyze the long-run trend in international integration in major equity markets; however, there are few studies on East Asian equity markets. A notable exception is a recent study by Boubakri and Guillaumin (2015), where the authors find an upward trend in the regional integration of East Asian stock markets after 2008 based on the international capital asset pricing model (ICAPM) with the dynamic conditional correlation (DCC) model.[3] In a similar vein, the first contribution of this current paper is to investigate the long-run trend of integration in the East Asian equity markets, namely, China, Hong Kong, Japan, and South Korea using the STC model based on the work of Berben and Jansen (2005) and Kumar and Okimoto (2011). Additionally, we note the fact that the East Asian equity markets open at almost the same time and decompose the equity returns into returns during trading hours (trading-hours returns) and returns after trading hours (after-trading-hours returns). Then, we examine the extent to which returns contribute more to the changes in integration in East Asian equity markets. This represents another contribution of the paper since there are few studies that analyze the dynamics of integration

[2] The countries where a significant rise in correlation with the US equity market is observed are France, Japan, Switzerland, and the UK. On the other hand, the countries where a significant rise in correlation is not observed are Canada and Germany.

[3] See Chi et al. (2006) and Park and Lee (2011) for other examples.

in global equity markets in a similar way.

Our analysis is summarized as follows. First, the analysis based on a two-regime STC model indicates that while there is little integration in the East Asian equity markets around the year 1995, the degree of integration has been increasing and is significantly greater around the year 2013 than the year 1995. Specifically, integration in the East Asian equity market significantly increased between 1995 and 2003 and has remained on a moderate upward trend since that period.

Second, our analysis using the decomposed returns demonstrates that a rise in integration after trading hours contributes to the increasing integration of East Asian equity markets to a greater extent than an increase in integration during trading hours

Third, we also examine the dynamics of East Asian equity market integration in a more flexible manner based on the three-regime STC model. We show that while the integrations between China and the other three countries have been growing significantly since 2007, integration among the three countries other than China has increased significantly between 1998 and 2001. We also find that this integration growth is caused by the correlation increases in after-trading hours. The period from 1998 to 2001, in which equity market integration among three countries other than China was promoted, is the period when the Asian currency crisis that began in 1997 came to an end, deregulation was conducted in the South Korean equity market, and the Hong Kong Stock Exchange was reformed. As a result, investments by European and US investors become active in East Asian equity markets other than China providing a possible explanation for the increase in integration in the after-trading-hours returns. On the other hand, since April 2005, before the start of growth in the East Asian equity market integration between China and the other three countries, China had been resolving various problems related to non-circulating shares (state-owned shares) and promoting share segregation reform to circulate non-circulating shares. By the end of 2006, 1,298 companies, or 98% of the target companies, had implemented the reform. Consequently, the credibility of the Chinese equity market has increased, and European and US investors have begun to actively invest in Chinese shares, suggesting that these investments greatly contribute to growth in integration in after-trading-hours returns between Chinese and other East Asian equity markets.

Finally, we assess the effects of increasing integration in East Asian equity markets on international asset allocation based on the minimum variance portfolio. Our results indicate that the weight of each country in the minimum variance portfolio investing in the four East Asian Equity markets was between 0.19 and 0.33 in 1995, whereas the weights in 2013 were more diverse with more than 60% weight for Japan and 0% weight for South Korea, suggesting a reduction of diversification effects. Therefore, one possible implication of our study is that it has become more important to make investments by closely examining industry sectors instead of simply investing simply in the typical country indexes when diversifying investments in the East Asian equity markets.

The structure of this paper is as follows: Section 2 introduces the STC model and its estimation strategy. Section 3 describes the estimation results of the two-regime STC model, Section 4 summarizes the results of the three-regime STC GARCH model. Finally, Section 5 presents the conclusion of our analysis.

2. Econometric Models and the Estimation Strategy

This paper uses an STC model with multiple regimes to analyze the dynamics of international integration in East Asian equity markets. The smooth-transition model has been applied to various models since statistical inference in smooth-transition autoregressive (AR) models is established by Teräsvirta (1994). In particular, Berben and Jansen (2005) and Kumar and Okimoto (2011) use two-regime STC models to examine correlation dynamics in international equity and bond markets, respectively. The purpose of this paper is to investigate the long-run trend of international integration in East Asian equity markets and, therefore, we adopt a multiple-regime STC model in accordance with these studies. The following section briefly explains the multiple-regime STC model and its estimation methodology.

2.1 Model

The basic model used in this paper is written as:

$$\mathbf{y}_t = \boldsymbol{\mu}_t + \mathbf{u}_t,$$

where $\mathbf{y}_t$ is a 4×1 vector consisting of the equity returns of China, Hong Kong, Japan, and South Korea, μ_t is a 4×1 vector expressing the conditional expected returns of $\mathbf{y}_t$, and $\mathbf{u}_t$ is the 4×1 disturbance vector of the model. We assume that the conditional expected equity returns of each country do not depend on the equity returns of other countries and can be modeled as the AR(2) model:[4]

$$y_{it} = \phi_{0i} + \phi_{1i} y_{i,t\text{-}1} + \phi_{2i} y_{i,t\text{-}2} + u_{it} \qquad (1)$$

In addition, we assume that $\mathbf{u}_t$ is written as

$$\mathbf{u}_t = \mathbf{H}_t^{1/2}\, \mathbf{z}_t,$$

where $\mathbf{H}_t$ is a 4×4 positive definite matrix, and $\mathbf{z}_t$ is a 4×4 iid random variable vector following a normal distribution with mean of zero and covariance matrix of unit matrix $\mathbf{I}_4$. In general, $\mathbf{H}_t$ can be expressed as

$$\mathbf{H}_t = \mathbf{D}_t \mathbf{R}_t \mathbf{D}_t,$$

Here, $\mathbf{R}_t$ is the time-varying correlation matrix of $\mathbf{y}_t$ **,** and $\mathbf{D}_t$ is a 4×4 diagonal matrix with the same diagonal elements as $\mathbf{H}_t$:[5]

$$\mathbf{D}_t = \mathrm{diag}(h_{11,t}^{1/2}, \ldots, h_{44,t}^{1/2}).$$

Moreover, we assume that each diagonal element of $\mathbf{H}_t$, or the volatility of each disturbance, follows

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[4] We also estimate a more general model based on the VAR model, but the equity returns of other countries are mostly insignificant, so this assumption is not unreasonable.

[5] $\mathrm{diag}(a_{11}, \cdots, a_{44})$ is a 4×4 diagonal matrix in which the ith diagonal element is equal to a_{ii} and the non-diagonal elements are equal to 0.

the GARCH (1,1) model:

$$h_{ii,t} = \omega_i + \beta h_{ii,t-1} + \alpha u_{i,t-1}^2. \qquad (2)$$

Thus, the marginal model of each variable is modeled by AR(2)-GARCH(1,1). Finally, we model $\mathbf{R}_t$ using a smooth-transition correlation model as follows:

$$\mathbf{R}_t = (1 - G(s_t\,;\gamma, c))\mathbf{R}^{(1)} + G(s_t\,;\gamma, c)\mathbf{R}^{(2)}. \qquad (3)$$

Here, $G(\cdot)$ is a transition function that takes a value from zero to one, and s_t is a transition variable. From (3), it is obvious that $\mathbf{R}t = \mathbf{R}^{(1)}$ when G=0, and $\mathbf{R}_t = \mathbf{R}^{(2)}$ when G =1. In other words, the STC model (3) has two regimes called $\mathbf{R}^{(1)}$ and $\mathbf{R}^{(2)}$ at both extremes and transitions smoothly between these two regimes depending on the value of the transition function. The transition function is modeled by the logistic function as:

$$G(s_t\,;\gamma, c) = \frac{1}{1+\exp(-\gamma(s_t - c))}\ , \gamma > 0,$$

where γ is a parameter that determines the speed of transition, and c is a parameter that determines the center of transition.[6] One of the advantages of a logistic transition function is that it can express various forms of transition depending on the values of γ and c. Additionally, γ and c can be estimated from data, enabling the selection of optimum transition patterns based on the data. Since the form of transition is generally unknown, the ability to estimate it from data is appealing.

The transition variable controls transition and is determined according to the purpose of the analysis from variables contained in Ω_{t-1}, where Ω_{t-1} is the information set consisting of variables observed by the end of time *t-1*. Since the purpose of this paper is to analyze the long-run trend of international integration in East Asian equity markets, the transition variable is taken as the time trend $s_t = t/T$, following Lin and Teräsvirta (1994) and Berben and Jansen (2005), where T is the sample size. In addition, we assume $0.05 < c < 0.95$ so that we can detect the correlation transition within the sample period. Under these assumptions, $G(s_t)$ takes the value close to zero with smaller s_t around the beginning of the sample period making $\mathbf{R}_t$ close to $\mathbf{R}^{(1)}$. Therefore, $\mathbf{R}^{(1)}$ can be considered as the correlation matrix around the beginning of the sample. In contrast, around the end of the sample, $\mathbf{R}_t$ approaches $\mathbf{R}^{(2)}$ as $G(s_t)$ approaches one. Thus, $\mathbf{R}^{(2)}$ can be considered the correlation matrix around the end of the sample. Specifically, under these assumptions, the time-varying correlation matrix $\mathbf{R}_t$ changes smoothly from $\mathbf{R}^{(1)}$ to $\mathbf{R}^{(2)}$ with time as $G(s_t)$ changes smoothly from zero to one. Moreover, the STC model allows data to choose the pattern of transition. The change is abrupt for large values of γ, whereas the transition is gradual for small values of γ. Additionally, the location parameter c can adjust the location of the reflection point. Thus, by estimating this STC model, we can estimate from the data when and how the transition of correlations occurs in East Asian equity markets, which

[6] Note that we assume that γ and c are common for all pairs. This assumption is necessary to make estimation more feasible as well as to conduct the test of equality of correlation across regimes for one pair without any identification problem. However, also note that this assumption is not that restrictive, as each pair's correlations can take very different values. For example, it is possible that one pair has monotonically increasing correlation, while another pair has monotonically decreasing correlation. In addition, we estimate the more general model allowing that γ and c for China-related pairs and pairs excluding China are different in Section 4.

is particularly useful for the purpose of this paper. Furthermore, we can test the changes in a correlation for a specific pair by testing the difference between the corresponding elements of $\mathbf{R}^{(1)}$ and $\mathbf{R}^{(2)}$. For example, if we want to test the changes in correlation between countries 1 and 2, we can test the difference between the (1, 2) elements of $\mathbf{R}^{(1)}$ and $\mathbf{R}^{(2)}$. More specifically, we can test the null hypothesis $H_1: r_{12}^{(1)} = r_{12}^{(2)}$ against the alternative hypothesis $H_1: r_{12}^{(1)} \neq r_{12}^{(2)}$, where $r_{12}^{(k)}$ is the (1, 2) element of $\mathbf{R}^{(k)}$.[7]

It is also possible to extend a two-regime STC model into models with three regimes or more. For example, we can extend the model (3) to three regimes as follows:

$$\mathbf{R}_t = \mathbf{R}_t^{(1)} + G_1(s_t; c_1,\gamma_1)(\mathbf{R}_t^{(2)} - \mathbf{R}_t^{(1)}) + G_2(s_t; c_2,\gamma_2)(\mathbf{R}_t^{(3)} - \mathbf{R}_t^{(2)}) \qquad (4)$$

Here, we assume, $0.05 < c_1 < c_2 < 0.95$. In other words, for a three-regime model we use two transition functions and multiply the functions by the difference between the correlation matrixes of adjacent regimes to express transition from one regime to another. In this model, when s_t is small or around the beginning of sample, $\mathbf{R}_t$ approaches the first regime correlation $\mathbf{R}^{(1)}$ because both $G_1(s_t)$ and $G_2(s_t)$ take small values near 0. When $c_1 < s_t < c_2$, $\mathbf{R}_t$ becomes close to the second regime correlation $\mathbf{R}^{(2)}$ because $G_1(s_t)$ tends to be near one, but $G_2(s_t)$ tends to be near zero. Finally, when $c_2 < s_t$, $\mathbf{R}_t$ is close to $\mathbf{R}^{(3)}$ with $G_1(s_t)$ and $G_2(s_t)$ taking values near one. Thus, under this specification, the time-varying correlation matrix $\mathbf{R}_t$ changes smoothly from $\mathbf{R}^{(1)}$ via $\mathbf{R}^{(2)}$ to $\mathbf{R}^{(3)}$ with time as first $G_1(s_t)$ changes from zero to one followed by a similar change in $G_2(s_t)$. The extent to which the correlation is close to each regime's correlation, and the way in which it becomes close, depends on the values of c and γ, which can be estimated from data making the multiple-regime STC model attractive for the examination of the dynamic of integration in East Asian equity markets.

2.2 Estimation strategy

Estimation of the multiple-regime smooth-transition correlation GARCH model is often performed based on the maximum likelihood estimation (MLE). However, in the case of a multiple-regime STC model, there are many parameters and, in some cases, numerical maximization of likelihood with respect to those parameters is not easy. For example, in this paper, the total number of parameters is 38 even for the two-regime STC model, and it is difficult to maximize likelihood with respect to 38 parameters. Therefore, we adopt a two-stage MLE, maximizing marginal likelihood and a likelihood related to correlation parameters separately to obtain the maximum likelihood estimates. This subsection briefly explains the two-stage MLE. For further details of the two-stage MLE, please refer to studies such as Joe (2005).

If $\mathbf{z}_t \sim N(\mathbf{0}, \mathbf{I}_4)$, the (conditional) log-likelihood can be written as

$$L(\theta) = -1/2\Sigma(n \log(2\pi) + \log|\mathbf{H}_t| + \mathbf{u}_t' \mathbf{H}_t^{-1} \mathbf{u}_t)$$
$$= -1/2\Sigma(n \log(2\pi) + \log \log|\mathbf{D}_t \mathbf{R}_t \mathbf{D}_t| + \mathbf{u}_t' \mathbf{D}_t^{-1} \mathbf{R}_t^{-1} \mathbf{D}_t^{-1} \mathbf{u}_t)$$

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[7] There is no identification problem for this test since we assume that γ and c are common for all pairs and other pairs can identify the value of γ and c.

$$= -1/2\Sigma(n \log(2\pi) + 2 \log|\mathbf{D}_t| + \mathbf{D}_t^{-1}\mathbf{u}_t' \mathbf{u}_t \mathbf{D}_t^{-1} + \log |\mathbf{R}_t| + \boldsymbol{\varepsilon}_t' \mathbf{R}^{-1}\boldsymbol{\varepsilon}_t - \boldsymbol{\varepsilon}_t'\boldsymbol{\varepsilon}_t)$$

Let the sum of the marginal log-likelihoods of each variable be $L_m(\theta_m)$ and the log-likelihood related to correlation be $L_c(\theta_c)$, namely,

$$L_m(\theta_m) = -1/2(n \log(2\pi) + 2 \log|\mathbf{D}_t| + \mathbf{D}_t^{-1}\mathbf{u}_t' \mathbf{u}_t \mathbf{D}_t^{-1})$$
$$= -1/2\Sigma(\log(2\pi) + \log h_{ii,t} + u_{it}^2/h_{ii})$$
$$L_c(\theta_c) = -1/2\Sigma(\log |\mathbf{R}_t| + \boldsymbol{\varepsilon}_t' \mathbf{R}^{-1}\boldsymbol{\varepsilon}_t - \boldsymbol{\varepsilon}_t'\boldsymbol{\varepsilon}_t)$$

Accordingly, the log-likelihood can be expressed as the sum of the two log-likelihoods as follows:

$$L(\theta) = L_m(\theta_m) + L_c(\theta_c)$$

In the two-stage MLE, first, we maximize each marginal log-likelihood to maximize the sum of each marginal log-likelihood $L_m(\theta_m)$ and obtain the marginal parameter estimates for each variable. Next, taking these marginal parameter estimates as given, we maximize the likelihood related to correlation $L_c(\theta_c)$ to obtain parameter estimates related to correlation. Specifically, we first apply AR(2)-GARCH(1,1) model (1)-(2) to the equity returns of each country and calculate the marginal parameters of each country's returns. Next, taking these estimates as given, we estimate the parameters of the multiple-regime STC model (3) or (4). For the two-stage MLE, because we estimate the marginal parameters and the correlation parameters separately, this may be less efficient than estimating all parameters simultaneously. However, this is a convenient method for estimating complex models such as the multiple-regime STC model. Additionally, there should be no major differences between the two methods if the sample size is large, which is the case in this paper with almost 1000 observations.

3. Results of the Two-regime STC Model

3.1 Data

The data used in this paper are daily equity indices for China (CH), Hong Kong (HK), Japan (JP), and South Korea (KR), and the sample period is from January 3, 1995 to January 30, 2013. For each country's equity index, we use the Shanghai Stock Exchange Composite Index (SSEC) for China, the Hang Seng Index (HSI) for Hong Kong, the Nikkei Stock Average 225 Index (Nikkei225) for Japan, and the Korea Composite Stock Price Index (KOSPI) for South Korea. We obtain the opening price (OP) and closing price (CP) of each index denominated in local currency from Bloomberg.

Based on the data obtained, we define three types of returns as follows. The first are commonly used equity returns (close-to-close returns or RCC), calculated by the log difference between a particular day's closing price and the previous day's closing price:

$$RCC_t = \log CP_t - \log CP_{t-1}$$

Next, we define trading-hours returns (open-to-close returns or ROC) as the log difference between a particular day's opening and closing prices:

$$ROC_t = \log CP_t - \log OP_t$$

Lastly, after-trading-hours returns (close-to-open returns or RCO) are defined by the log difference between a particular day's opening price and the previous day's closing price:

$$RCO_t = \log OP_t - \log CP_{t-1}$$

Based on the above definitions, it can be easily confirmed that equity returns can be broken down into trading-hours returns and after-trading-hours returns:

$$\begin{aligned} RCC_t &= \log CP_t - \log CP_{t-1} \\ &= \log CP_t - \log OP_t + \log OP_t - \log CP_{t-1} \\ &= RCO_t + ROC_t \qquad (5) \end{aligned}$$

Subsection 3.2 analyzes equity returns to examine the changes in international integration of East Asian equity markets. We then conduct the same analysis using trading-hours returns and after-trading-hours returns and assess to which returns changes in international integration of equity returns can be attributed. Regarding daily data, trading days differ among countries because of differences in national holidays, and there are many days when the data for the four countries cannot be obtained. Therefore, the actual analysis is conducted by summing the returns from the closing price of the Wednesday of the previous week to the closing price of the Wednesday of the following week and calculating weekly returns for each type of return. Note, however, that the decomposition of returns in (5) is still valid for weekly returns.

3.2 The dynamics of international integration in equity returns

We apply the AR(2)-GARCH(1,1)-two-regime STC model (1)-(3) to stock returns, RCC, of four East Asian markets. Table 1 summarizes the estimation results. As can be seen, the correlation estimates for each country pair for the first regime suggest that the correlations in regime 1 are low, with the highest correlation estimate of 0.006 for the HK-JP pair, the lowest correlation estimate of -0.283 for the CH-HK pair, and an average correlation of -0.125. If we consider statistical significance, the results show that no significant correlation exists for any country pairs. For the STC model with time trend as a transition variable, correlations in the first regime can be considered correlations around the beginning of the sample as discussed in the previous section, and this result indicates that there is essentially no international integration in the East Asian equity market around the year 1995.

In contrast, the correlation estimates for each country pair in the second regime are significantly positive and uniformly higher than those in the first regime. Specifically, the highest correlation estimate is 0.723 for the HK-KR pair, the lowest is 0.222 for the CH-JP pair, and the average is 0.485. The test results of the null hypothesis that correlations in the first and second regimes are equal are shown in the final two rows of Table 1. These test results suggest that correlations in the second regime are significantly higher than correlations in the first regime for all pairs at least at the 10% significance level. Since correlations in the second regime can be construed as correlations around the end of the sample, this result demonstrates that international integration in East Asian equity markets around the year 2013 is significantly greater than international integration around 1995 and international integration has increased in recent years.

When and how has the international integration of equity returns in East Asian equity markets increased? To answer this question, Figure 1 shows the correlation dynamics for each country pair based on the estimation results of the two-regime STC model. As can be seen, the correlation for each country pair, hence, international integration in East Asian equity markets increased greatly between 1995 and 2003 and remained on a moderate upward trend after that.

3.3 The dynamics of international integration of trading-hours returns

The previous subsection confirmed that East Asian equity market integration has increased based on equity returns. In this section and the following subsections, we assess whether this increase is largely attributable to trading-hours returns or after-trading-hours returns. To this end, we apply the same AR(2)-GARCH(1,1)-two-regime STC model (1)-(3) to trading-hours returns and summarize the estimation results in Table 2. We see that the correlation estimates for each country pair in the first regime are low with the highest correlation estimate of 0.076 for the CH-JP pair, the lowest correlation estimate of -0.287 for the CH-HK pair, and an average of -0.092. If we consider statistical significance, the results show that no significant correlation exists for any of the pairs. This result is similar to the result for equity returns, suggesting that there was essentially no international integration in the East Asian equity market around 1995 based on the trading-hours returns.

On the other hand, the correlation estimates for each country pair in the second regime are generally higher than those in the first regime, with the highest correlation estimate of 0.459 for the JP-KR pair, the lowest correlation estimate of 0.069 for the CH-JP pair, and an average of 0.272. However, the increase in correlation is uniformly smaller than in the case of equity returns. The results also show that there is no significant positive correlation for the CH-HK and JP-KR pairs. Additionally, the final two rows in Table 2 shows the results of testing the equivalence of correlations across two regimes and indicate that, even with a 10% significance level, the CH-HK and JP-KR pairs are the only two pairs in which the correlations in the second regime are significantly higher than the correlations in the first regime.

Finally, Figure 2 shows the dynamics of correlation for each country pair based on the estimation results to show visually the dynamics of international integration in East Asian equity markets based on trading-hours returns. The figure shows that correlation has increased greatly between the year 1995 and the year 2003 for the CH-HK and JP-KR pairs, but the increase has been modest for the remaining pairs.

In summary, while international integration of trading-hours returns trended upward as 2013 approached, the CH-HK pair and the JP-KR pair are the only two pairs with a significant increase, and the increase can be described as small compared to the increase in equity return international integration.

3.4 The dynamics of international integration of after-trading-hours returns

To assess the contribution of after-trading-hours returns to the increase in international integration of equity returns in East Asian equity markets, we apply the AR(2)-GARCH(1,1)-two-regime STC model (1)-(3) to after- trading-hours returns. Table 3 shows the estimation results for the correlation estimates for each country pair in the first regime, the highest correlation estimate is 0.558 for the HK-JP pair, the lowest is -0.158 for the CH-JP pair, and the average is 0.135. If we take statistical significance into consideration, there is a significant negative correlation for the CH-JP and CH-KR pairs. In contrast, there is a positive significant correlation for all pairs that do not include China. Thus, our results indicate that for after-trading-hours returns, there is essentially no integration between China and other East Asian markets around the year 1995, but a certain degree of integration exists among the markets in Hong Kong, Japan, and South Korea.

On the other hand, the correlation estimates for each country pair in the second regime are significantly positive with the highest correlation estimate of 0.832 for the HK-KR pair, the lowest of 0.450 for the CH-JP pair, and an average of 0.630. Additionally, the results of testing the equivalence of correlations across the two regimes shown in the last two rows of Table 3 suggest that the correlations in the second regime are significantly higher than the correlations in the first regime for all pairs.

Finally, Figure 3 shows the correlation dynamics for each country pair based on estimation results to visually examine the dynamics of integration of after-trading-hours returns in East Asian equity markets. The figure illustrates that East Asian equity market integration shows a modest upward trend in the year 1995, increased significantly between the year 1999 and the year 2005 and maintained a modest upward trend after that. The increase for China-related pairs is particularly remarkable, and correlations that were negative in 1995 rose to a level exceeding 0.4 in 2013. For other country pairs, although the increase is not as great as that of the China-related pairs, the correlation increased to around 0.8 by the year 2013 having been comparatively higher than that in 1995.

In summary, the integration of after-trading-hours returns in East Asian equity markets increased significantly between 1995 and 2005, and the increase in integration of equity returns in East Asian equity markets is largely attributable to after-trading-hours returns.

4. Results of the Three-regime STC Model

The results discussed thus far are based on the two-regime assumption. In other words, they are the results of analysis performed under the assumption that a monotonic trend exists in the international integration of East Asian equity markets. However, during the period from 1995 to 2013, it is not certain that a long-run trend is monotonic given the many significant events such as the Asian crisis and the Lehman shock. For example, suppose there was a temporary increase in East Asian equity market integration at the time of the Lehman crisis in 2008, but we still apply the two-regime STC model. Then, we could find an increasing trend in East Asian equity market integration similar to the trend obtained above. Therefore, in this section, we outline the results based on the three-regime STC model to assess the possibility of the existence of a non-monotonic trend.

4.1 Results of an unconstrained three-regime model

To examine the possible non-monotonic trend of East Asian equity market integration, we apply the AR(2)-GARCH(1,1)-three-regime STC model consisting of (1), (2), and (4) to equity returns, trading-hours returns, and after-trading-hours returns. Figures 4, 5, and 6 show the results of the estimated dynamics of correlation where there are several observations worth noting. First, it is clear from Figure 4 that the results for equity returns even allowing for a non-monotonic trend in the dynamics of correlation imply that international integration has increased almost monotonically for all pairs and, by the year 2013, correlation reached 0.638 on average. Regarding the timing of the increase in international integration, Figure 4 shows a slight difference between the China-related pairs and pairs excluding China. Specifically, for the China-related pairs, international integration increased greatly from 2008, whereas for the pairs excluding China, international integration increased markedly between the years 1995 and 2001.

Second, as can be seen from Figure 5 showing the results for trading-hours returns, the dynamics of the integration of trading-hours returns differ considerably from those of equity returns. Particularly, for the China-related pairs, this difference is striking, and the increase in international integration seen from the year 2008 for equity returns cannot be observed at all for trading-hours returns. Additionally, during the first half of the sample period, the CH-HK pair is the only pair exhibiting an increase in international integration. For the pairs excluding China, an increase in international integration is seen only during the first half of the sample period, and the extent of this increase is small compared to that of equity returns. Therefore, we argue that only a small part of the increase in international integration in East Asian equity markets is attributable to an increase in international integration of trading-hours returns, which is consistent with the results of the two-regime model.

Finally, Figure 6 showing the results for after-trading-hours returns demonstrates that dynamics of the integration of after-trading-hours returns are similar to those of equity returns. Specifically, international integration increased almost monotonically throughout the sample period for all pairs, but there is a difference in the timing of the increase between the China-related pairs and the pairs excluding China. For the China-related pairs, international integration was almost constant until the year 2007 but has increased significantly since 2007. In contrast, for the pairs excluding China, international integration increased between 1998 and 2001 and has remained almost constant since that period. Accordingly, the increase in international integration of equity returns in East Asian equity markets observed in Figure 4 can be explained largely by after-trading-hours returns, which is consistent with the results of the two-regime model.

The above results provide confirmation that even allowing for a non-monotonic trend in the model, qualitatively, the same results for the increase in the international integration of East Asian equity markets are obtained as the results for the two-regime model.

However, a difference between the two-regime model and the three-regime model was observed in terms of the timing of increases in international integration. Specifically, in the case of equity returns and after-trading-hours returns, the China-related pairs' international integration increased significantly after the year 2008, whereas international integration for the pairs excluding China increased significantly around the year 2000. This result shows that there is a difference between China-related pairs and pairs excluding China in terms of international integration regime transition and strongly suggests that the two-regime model, which assumes the same regime transition for China-related pairs and pairs excluding China, is an incorrect model. The result, however, could also imply the argument that, with respect to China-related pairs and pairs excluding China, an analysis using a two-regime model is sufficient, suggesting that our three-regime model is an over-parameterized model. Based on the above observations, subsection 4.2 estimates a constrained three-regime model assuming two regimes for China-related pairs and pairs excluding China.

4.2 Results of the constrained three-regime model

This subsection discusses the estimation results of a constrained three-regime model assuming two regimes for China-related pairs and pairs excluding China. More specifically, taking into consideration the differences between China-related pairs and pairs excluding China in terms of the timing of the increase in international integration, we impose $r_{ij}^{(1)} = r_{ij}^{(2)}$ for China-related pairs and $r_{ij}^{(2)} = r_{ij}^{(3)}$ for pairs excluding China on the three-regime STC model (4). Here, $r_{ij}^{(k)}$ is the (i, j) element for the correlation matrix $\mathbf{R}^{(k)}$. The regimes of the correlation matrices still consist of three regimes. However, as a result of these constraints, in the transition from the first to the second regime, only the correlations of pairs excluding China change, whereas in the transition from the second to the third regime only the correlations of China-related pairs change. Hereinafter, we shall refer to this model as the constrained three-regime STC model.

Table 4 shows the correlation matrix estimation results for the first and third regimes obtained through the application of the constrained three-regime STC model to equity returns.[8] The table shows that the correlation estimates for each country pair in the first regime are generally low with a highest correlation estimate of 0.070 for the HK-KR pair, a lowest correlation estimate of -0.119 for the JP-KR pair, and an average correlation estimate of -0.009. If we consider statistical significance,

[8] For the marginal models for each country, we use AR(2)-GARCH(1,1) model (1)-(2) as in the previous section. The same also applies for the during-hours and after-hours returns. It should be also noted that, as explained above, for the China-related pairs, the correlations in the second regime are equal to those in the first regime, whereas for the pairs excluding China the correlations in the second regime are equal to those in the third regime. This implies that correlations in the second regime can be obtained easily from correlations in the first and third regimes.

the results show that no significant correlation exists for any of the pairs, which is similar to the result for the two-regime model. Therefore, we conclude that there is virtually no international integration in East Asian equity markets around 1995 based on equity returns.

In contrast, correlation estimates for all country pairs in the third regime are higher than those for the first regime and significantly positive with the highest correlation of 0.765 for the CH-HK pair, the lowest correlation of 0.451 for the CH-JP pair, and an average of 0.620. Additionally, the test results of the equivalence of correlations between the first and third regimes shown in the final two rows of Table 4 indicate that the correlations in the third regime are significantly higher than the correlations in the first regime for all pairs. These results suggest that international integration of East Asian equity markets increased substantially during the period from 1995 to 2013, which is consistent with the results of the two-regime model.

Figure 7 shows the dynamics of the correlation of each pair based on the estimation results of the constrained three-regime STC model to investigate more specifically when and how the international integration of East Asian equity markets increased. It is clear from Figure 7 that for the constrained three-regime model, international integration has increased monotonically for all pairs and the correlation reached around 0.561 on average by 2013. As with the unconstrained three-regime model, a difference between China-related pairs and pairs excluding China in terms of the timing of the increase in international integration can be seen. Specifically, for the China-related pairs, international integration has increased greatly from 2004, whereas for the pairs excluding China, international integration has increased markedly between the years 1998 and 2001, which is consistent with the results from the unconstrained three-regime model. However, it could be argued that the results are more natural with no pairs having a declining correlation regime.

Next, Table 5 shows the correlation matrix estimation results for the first and third regimes obtained from the application of the constrained three-regime STC model to trading-hours returns. The results suggest that the correlation estimates for each country pair in the first regime are generally low with the highest correlation estimate of 0.099 for the HK-KR pair, the lowest of -0.265 for the CH-HK pair, and an average of 0.065. If we take statistical significance into consideration, the results show that no significant correlation exists for any of the pairs, which is consistent with the results for equity returns. Therefore, we conclude that there is virtually no international integration in East Asian equity markets around 1995 based on trading-hours returns.

On the other hand, the correlation estimates for each country pair in the third regime are higher than in the first regime, with the highest correlation estimate of 0.465 for the JP-KR pair, the lowest of 0.091 for the CH-JP pair, and an average of 0.298. However, compared to the results for equity returns, the increase relative to the first regime is minor. Particularly, for the China-related pairs, the correlations in the third regime are not significant for any of these pairs. In addition, regarding the CH-JP and CH-KR pairs, we do not find a significant increase in correlation.

Figure 8 confirms these points showing the dynamics of estimated correlations from the constrained three-regime STC model applied to the trading-hours returns. For the pairs excluding

China, the correlation dynamics show a comparatively modest increase between 1995 and 2001 and are almost constant from the year 2001. For the China-related pairs, the correlation dynamics suggest a modest increase for the period from 1995 to 2010 only for the CH-HK pair and no significant increase for the other two pairs. Thus, it is fair to say that the increase in international integration has been limited for trading-hours returns.

Finally, Table 6 shows the correlation matrix estimation results for the first and third regimes obtained from the application of the constrained three-regime STC model to after-trading-hours returns. The results indicate that there are no significant correlations for all pairs except for the HK-JP pair with the highest correlation estimate of 0.478 for the HK-JP pair, the lowest of -0.063 for the JP-KR pair, and an average of 0.067. Therefore, we conclude that there is no strong international integration in East Asian equity markets around the year 1995, with the exception of the HK-JP pair, based on after-trading-hours returns.

In contrast, the correlation estimates in the third regime are significantly positive for all pairs, with the highest correlation estimate of 0.768 for the HK-KR pair, the lowest of 0.605 for the CH-JP pair, and an average of 0.691. Additionally, the results show that correlations in the third regime are significantly higher than the correlations in the first regime for all pairs, as can be seen in the final two rows of Table 6.

Figure 9 shows the correlation dynamics for each country pair based on the estimation results to visually confirm when and how the increase in correlation of after-trading-hours returns in East Asian equity markets occurred. It is clear from Figure 9 that for the pairs excluding China, correlation increased greatly during the period from 1998 to 2001, whereas for the China-related pairs correlation increased markedly from the year 2007. The increase in correlation for all pairs except the HK-JP is particularly remarkable, and correlation has risen from almost zero in the year 1995 to a level exceeding 0.6 in the year 2013. For the HK-JP pair, the increase was not as marked as the increase for other pairs, but the correlation was nonetheless around 0.7 in 2013 having been high initially in 1995.

To sum up the above results, international integration of equity returns in East Asian equity markets increased substantially between the year 1998 and the year 2001 for pairs not including China and increased from 2007 for the China-related pairs. Thus, our results demonstrate that the contribution of trading-hours returns to the increase is minor, and the increase is largely attributable to after-trading-hours returns.

4.3 Impact on diversified investment

Our analysis shows that the international integration of East Asian equity markets has increased significantly. This subsection examines briefly the impact of the increase in international integration in East Asian equity markets from the international asset allocation perspective.

When international integration increases, the effect of diversification is reduced, implying less reason to engage in international asset allocation. Alternatively, from the perspective of optimizing asset allocation, if international integration in East Asian equity markets is low, then investing a certain percentage in each market is advisable. Conversely, if international integration is high, then concentrating investment in a single country may be optimal. From this perspective, Table 7 documents the weights of investment on each market in the minimum variance portfolio based on the levels of correlation in the year 1995 and the year 2013.[9] The results of equity returns suggest that the minimum variance portfolio in 1995 invests in all four markets with nearly equal weight, ranging from 0.20 to 0.35. In contrast, the minimum variance portfolio in the year 2013 is heavily biased with Japan accounting for almost 60% of the total portfolio and no investment in South Korea. This clearly indicates that for equity returns, which have become much more internationally integrated, the diversification effects reduced in the year 2013 compared with the year 1995.

On the other hand, the results for trading-hour returns suggest that there is no noticeable change in the minimum variance portfolio weights, and the minimum variance portfolio is still comprised of investments in all countries in the year 2013. This is not surprising considering that international integration of trading-hours returns has not increased significantly. In contrast, the results for after-trading-hours returns show a similar tendency to those of equity returns, and the decline in the diversification effects is more noticeable. For the after-trading-hours returns, because the correlation for the HK-JP pair was already comparatively high in 1995, the weight for Hong Kong is 0.02, and the weight for Japan exceeded 0.5. By the year 2013, international integration has increased for all pairs reducing the diversification effects. As a result, the minimum variance portfolio is extremely biased, with Japan accounting for more than 90% of total investment.

In summary, for East Asian equity markets, the effects of international asset allocation are vastly reduced for equity returns and after-trading-hours returns. While international asset allocation still has a slight effect on trading-hours returns, investing during regular trading hours only is unrealistic from a long-term investment perspective. Therefore, when engaging in international asset allocation in East Asian equity markets, it is now important to consider further diversification, such as industrial sector diversification, rather than simply investing in each country's leading index.

5. Conclusion

This paper analyzed whether the international integration of East Asian equity markets increased significantly during the period from 1995 to 2013 and, if so, approximately when and how this increase occurred. To this end, we used multiple-regime smooth transition correlation (STC) models to estimate the long-run trend in the international integration of East Asian equity markets, namely, the China (CH), Hong Kong (HK), Japan (JP), and South Korean (KR) markets. Additionally, we noted that the East Asian equity markets open at almost the same time and decompose the equity

[9] We used the estimates obtained by the constrained three-regime STC model as the correlations. We also assumed that the volatility of each country's equity returns was average over the sample period and remained constant to solely investigate the impact of correlation.

returns into trading-hours returns and after-trading-hours returns. Then, we examined the extent to which returns contributed to the changes in integration in East Asian equity markets.

Our results of the two-regime STC model showed that there was virtually no international integration in the East Asian equity markets around the year 1995, the level of international integration of East Asian equity markets around the year 2013 was significantly higher than that of 1995. Specifically, international integration of East Asian equity markets has increased significantly during the period from 1995 to 2003 and has maintained a moderate upward trend since then. In addition, our analysis using the decomposed returns demonstrated that a rise in integration after trading hours contributes more than an increase in integration during trading hours to increasing integration in the East Asian equity markets.

When we used a three-regime STC model to examine the dynamics of international integration of East Asian equity markets in a more flexible manner, the results showed that the integration between China and the other three countries has been growing significantly since 2007, and the integrations among the three countries other than China increased significantly between 1998 and 2001. We also discovered that this increase in international integration was largely attributable to an increase in international integration of after-trading-hours returns.

Our evaluation of the impact of this increase in international integration on the diversification effect based on the minimum variance portfolio demonstrated that the diversification effects decreased as international integration increased. More specifically, our evaluation confirmed that while the minimum variance portfolio in 1995 invested on all four markets with relatively equal weights, ranging from 0.20 to 0.35, the minimum variance portfolio in 2013 was heavily biased with Japan accounting for more than 60% of the total portfolio and no investment in South Korea, suggesting a reduction of diversification effects. One possible implication is, therefore, that when engaging in international asset allocation in East Asian equity markets, it is important to consider further diversification such as industrial sector diversification rather than simply investing in each country's leading index.

The results of the paper established that although international integration of East Asian equity markets increased, this increase was largely attributable to after-trading-hours returns. The main cause of changes in stock prices during after-trading-hours is often the European and US equity markets and the results suggest that investment in East Asian equity markets by European and US investors becomes more influential, and stock prices have been affected by the European and US equity markets to a greater extent in more recent years. In fact, the period during which international integration increased significantly was from the year 1998 to the year 2001 in the case of pairs excluding China. This period coincides with a letup in the Asia currency crisis that began in 1997 and more aggressive investment activity by European and American investors in East Asian equity markets other than China. These circumstances provide a possible explanation for the increase in integration in the after-trading-hours returns. Developments, such as the deregulation of the equity market in South Korea and the reform of the equity market exchange in Hong Kong in the wake of the currency crisis, may also have contributed to the increase in international integration.

Since April 2005, prior to the increase among China-related pairs, split-share structure (non-tradable share) reform has been implemented in China to solve the circulation problem of non-tradable shares (state-owned shares) and, by the end of 2006, 1,298 companies, or 98% of listed companies, had implemented reforms. As a result, confidence in the equity market grew, investment in Chinese equity by European and US investors also increased, and this may have been a major contributing factor to the increase in international integration of after-trading-hours returns for the China-related pairs.

The above observations are only based on the timing of the increase in international integration, and a more comprehensive analysis of the causes of the increase in international integration is an important issue to be addressed in the future. Finally, in this paper, we conducted all our analysis based solely on national currency denominated returns. A similar analysis could be performed for returns denominated in the currency of the investing country, for example, returns denominated in yen, and it would also be interesting to examine the effect of foreign exchange gains and the effect of foreign exchange hedges, but these are subjects for future research.

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Table 1: Estimation results of equity return correlations (two-regime model)

		CH-HK	CH-JP	CH-KR	HK-JP	HK-KR	JP-KR
Regime1	Estimate	-0.283	-0.078	-0.210	0.006	0.005	-0.193
	Std. Error	0.248	0.137	0.185	0.212	0.261	0.276
Regime2	Estimate	0.419***	0.222***	0.262***	0.619***	0.723***	0.662***
	Std. Error	0.047	0.043	0.048	0.030	0.031	0.030
Test of equality	Wald stat	6.44	3.51	4.92	7.17	6.43	8.56
	P-VALUE	0.011	0.061	0.027	0.007	0.011	0.003

Note: Table 1 reports the estimation results of equity return correlations for the two-regime STC model with $s_t = t/T$, where T is the sample size. The second and third row show the estimated correlation and its standard error for Regime 1 for each commodity pair, while the fourth and fifth rows report the estimated correlation and its standard error for Regime 2. The last two rows document the Wald statistic and its p-value to test the null hypothesis of the equivalence of correlation across regimes. */**/*** indicate that the variable is significant at the 10%/5%/1% level of significance, respectively.

Table 2: Estimation results of trading-hours return correlations (two-regime model)

		CH-HK	CH-JP	CH-KR	HK-JP	HK-KR	JP-KR
Regime1	Estimate	-0.287	0.076	-0.127	-0.015	0.040	-0.239
	Std. Error	0.320	0.105	0.162	0.182	0.203	0.364
Regime2	Estimate	0.287***	0.069	0.127**	0.308***	0.381***	0.459***
	Std. Error	0.047	0.044	0.052	0.039	0.038	0.044
Test of equality	Wald stat	2.771	0.002	1.885	2.656	2.462	3.418
	P-VALUE	0.096	0.962	0.170	0.103	0.117	0.065

Note: Table 2 reports the estimation results of trading-hours return correlations for the two-regime STC model with $s_t = t/T$, where T is the sample size. The second and third row show the estimated correlation and its standard error for Regime 1 for each commodity pair, while the fourth and fifth rows report the estimated correlation and its standard error for Regime 2. The last two rows document the Wald statistic and its p-value to test the null hypothesis of the equivalence of correlation across regimes. */**/*** indicate that the variable is significant at the 10%/5%/1% level of significance, respectively.

Table 3: Estimation results of after-trading-hours return correlations (two-regime model)

		CH-HK	CH-JP	CH-KR	HK-JP	HK-KR	JP-KR
Regime1	Estimate	-0.082	-0.158**	-0.142**	0.558***	0.334***	0.298***
	Std. Error	0.062	0.066	0.060	0.047	0.114	0.119
Regime2	Estimate	0.519***	0.456***	0.450***	0.723***	0.832***	0.798***
	Std. Error	0.106	0.103	0.116	0.023	0.024	0.026
Test of equality	Wald stat	28.572	33.101	22.597	8.899	19.553	17.333
	P-VALUE	0.000	0.000	0.000	0.003	0.000	0.000

Note: Table 3 reports the estimation results of after-trading-hours return correlations for the two-regime STC model with $s_t = t/T$, where T is the sample size. The second and third row show the estimated correlation and its standard error for Regime 1 for each commodity pair, while the fourth and fifth rows report the estimated correlation and its standard error for Regime 2. The last two rows document the Wald statistic and its p-value to test the null hypothesis of the equivalence of correlation across regimes. */**/*** indicate that the variable is significant at the 10%/5%/1% level of significance, respectively.

Table 4: Estimation results of equity return correlations (constrained three-regime model)

		CH-HK	CH-JP	CH-KR	HK-JP	HK-KR	JP-KR
Regime1	Estimate	-0.001	-0.003	-0.066	0.064	0.070	-0.119
	Std. Error	0.058	0.054	0.073	0.070	0.081	0.130
Regime3	Estimate	0.765***	0.451***	0.573***	0.599***	0.699***	0.634***
	Std. Error	0.129	0.067	0.082	0.025	0.025	0.025
Test of equality	Wald stat	32.98	22.04	61.93	41.41	44.64	27.38
	P-VALUE	0.000	0.000	0.000	0.000	0.000	0.000

Note: Table 4 reports the estimation results of equity return correlations for the constrained three-regime STC model with $s_t = t/T$, where T is the sample size. The second and third row show the estimated correlation and its standard error for Regime 1 for each commodity pair, while the fourth and fifth rows report the estimated correlation and its standard error for Regime 2. The last two rows document the Wald statistic and its p-value to test the null hypothesis of the equivalence of correlation across regimes. */**/*** indicate that the variable is significant at the 10%/5%/1% level of significance, respectively.

Table 5: Estimation results of trading-hours return correlations (constrained three-regime model)

		CH-HK	CH-JP	CH-KR	HK-JP	HK-KR	JP-KR
Regime1	Estimate	-0.265	0.026	-0.158	0.035	0.099	-0.126
	Std. Error	0.685	0.099	0.366	0.092	0.100	0.395
Regime3	Estimate	0.360	0.091	0.179	0.312***	0.383***	0.465*
	Std. Error	0.377	0.113	0.217	0.121	0.080	0.257
Test of equality	Wald stat	2.975	0.116	2.450	3.124	6.544	9.808
	P-VALUE	0.085	0.733	0.118	0.077	0.011	0.002

Note: Table 5 reports the estimation results of trading-hours return correlations for the constrained three-regime STC model with $s_t = t/T$, where T is the sample size. The second and third row show the estimated correlation and its standard error for Regime 1 for each commodity pair, while the fourth and fifth rows report the estimated correlation and its standard error for Regime 2. The last two rows document the Wald statistic and its p-value to test the null hypothesis of the equivalence of correlation across regimes. */**/*** indicate that the variable is significant at the 10%/5%/1% level of significance, respectively.

Table 6: Estimation results of after-trading-hours return correlations (constrained three-regime model)

		CH-HK	CH-JP	CH-KR	HK-JP	HK-KR	JP-KR
Regime1	Estimate	0.026	-0.031	-0.017	0.478***	0.011	-0.063
	Std. Error	0.032	0.025	0.024	0.052	0.046	0.070
Regime3	Estimate	0.704***	0.605***	0.631***	0.700***	0.768***	0.740***
	Std. Error	0.030	0.023	0.023	0.017	0.012	0.013
Test of equality	Wald stat	427.159	265.675	404.904	13.741	253.858	125.561
	P-VALUE	0.000	0.000	0.000	0.000	0.000	0.000

Note: Table 6 reports the estimation results of equity return correlations for the constrained three-regime STC model with $s_t = t/T$, where T is the sample size. The second and third row show the estimated correlation and its standard error for Regime 1 for each commodity pair, while the fourth and fifth rows report the estimated correlation and its standard error for Regime 2. The last two rows document the Wald statistic and its p-value to test the null hypothesis of the equivalence of correlation across regimes. */**/*** indicate that the variable is significant at the 10%/5%/1% level of significance, respectively.

Table 7: Optimal weights for minimum variance portfolio

		CH	HK	JP	KR
Equity returns	1995	0.242	0.210	0.346	0.202
	2013	0.287	0.118	0.595	0.000
Trading-hours returns	1995	0.222	0.284	0.297	0.197
	2013	0.232	0.294	0.390	0.085
After-trading-hours returns	1995	0.250	0.024	0.538	0.188
	2013	0.073	0.000	0.927	0.000

Note: Table 7 reports the optimal weights for minimum variance portfolio in 1995 and 2013 using the estimation results of each return correlation for the constrained three-regime STC model with $s_t = t / T$, where T is the sample size.

Figure 1: Dynamics of equity return correlation (two-regime model)

Figure 1 plots the dynamics of equity return correlation for each country-pair based on the two-regime STC model with $s_t = t/T$, where T is the sample size.

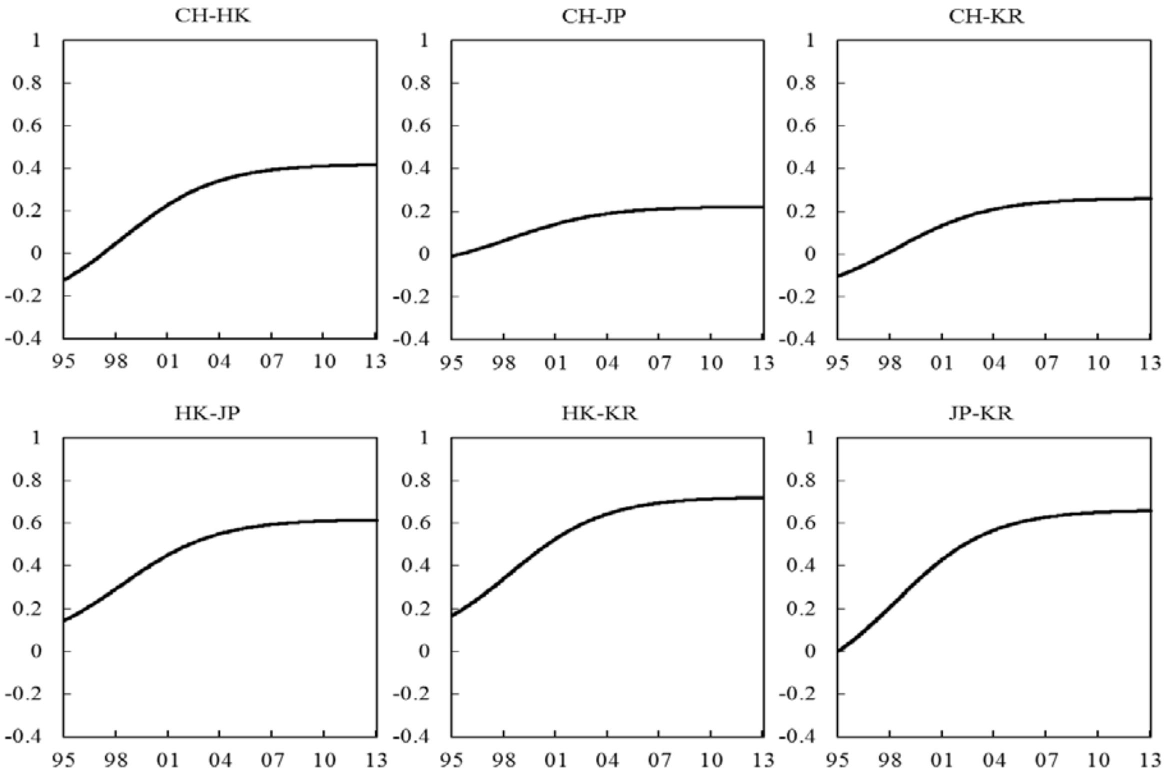

Figure 2: Dynamics of trading-hours return correlation (two-regime model)

Figure 2 plots the dynamics of trading-hours return correlation for each country-pair based on the two-regime STC model with $s_t = t / T$, where T is the sample size.

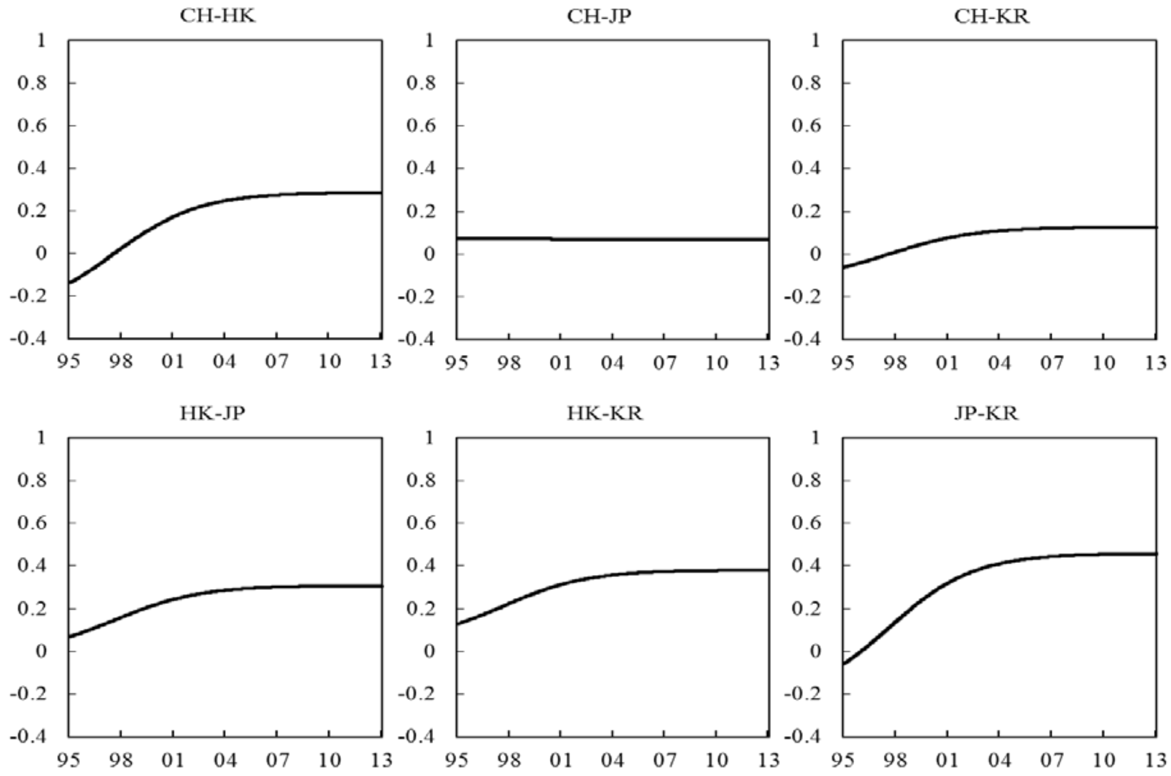

Figure 3: Dynamics of after-trading-hours return correlation (two-regime model)

Figure 3 plots the dynamics of after-trading-hours return correlation for each country-pair based on the two-regime STC model with $s_t = t/T$, where T is the sample size.

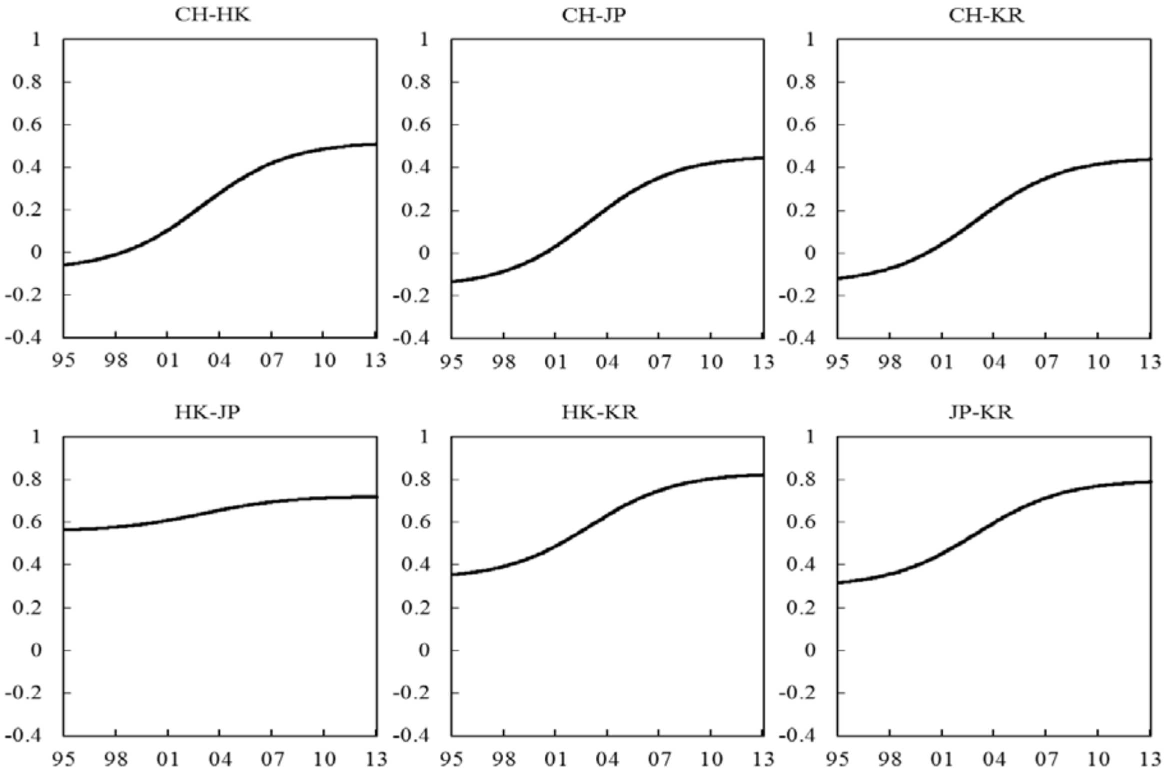

Figure 4: Dynamics of equity return correlation (unconstrained three-regime model)

Figure 4 plots the dynamics of equity return correlation for each country-pair based on the unconstrained three-regime STC model with $s_t = t/T$, where T is the sample size.

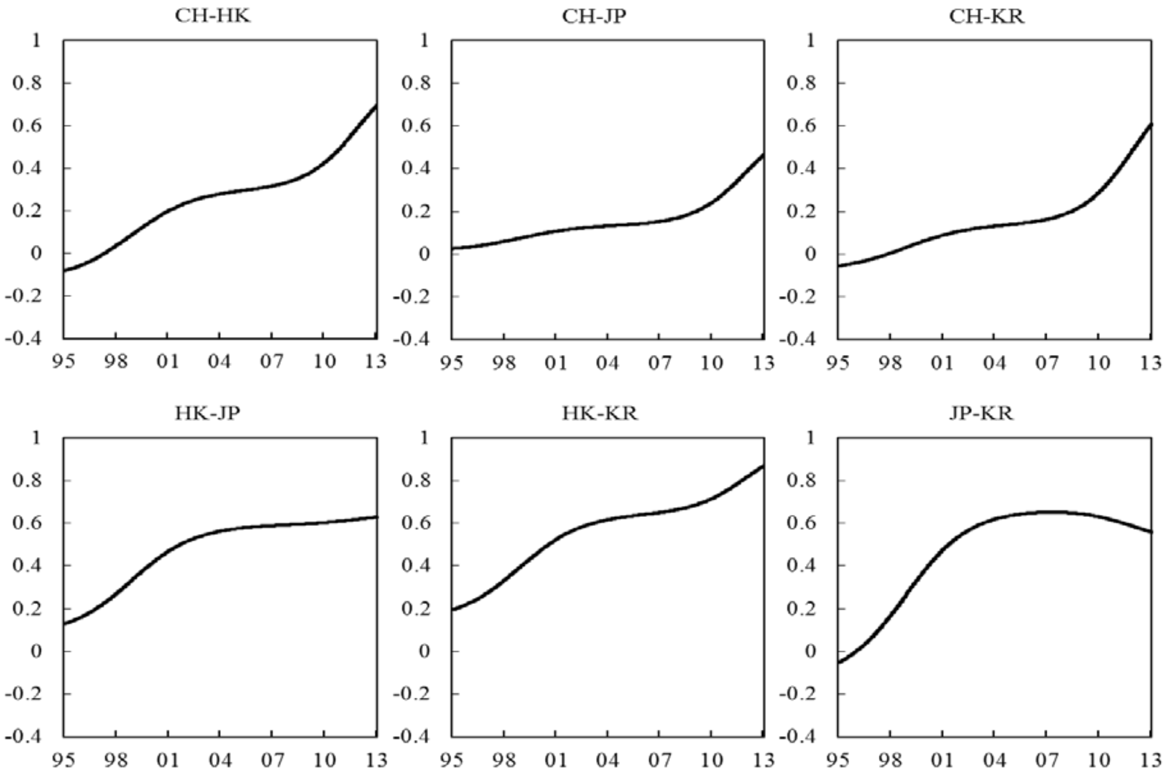

Figure 5: Dynamics of trading-hours return correlation (unconstrained three-regime model)

Figure 5 plots the dynamics of trading-hours return correlation for each country-pair based on the unconstrained three-regime STC model with $s_t = t / T$, where T is the sample size.

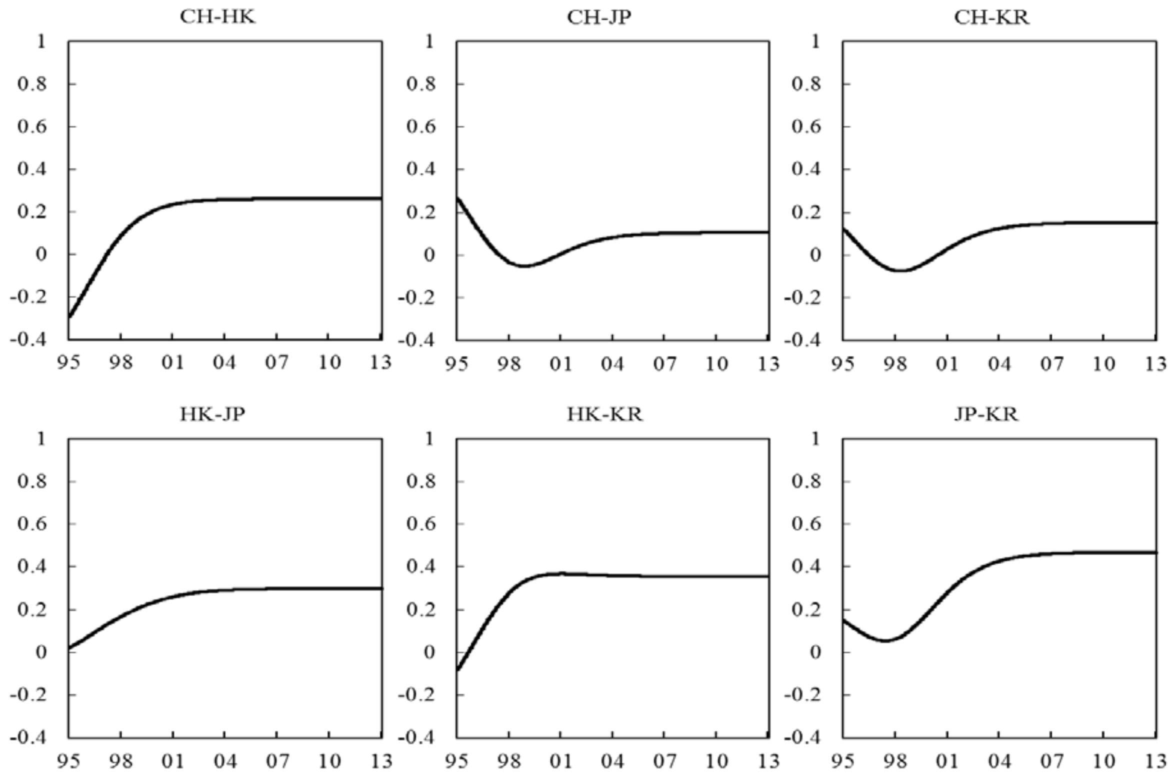

Figure 6: Dynamics of after-trading-hours return correlation (unconstrained three-regime model)

Figure 6 plots the dynamics of after-trading-hours return correlation for each country-pair based on the unconstrained three-regime STC model with $s_t = t/T$, where T is the sample size.

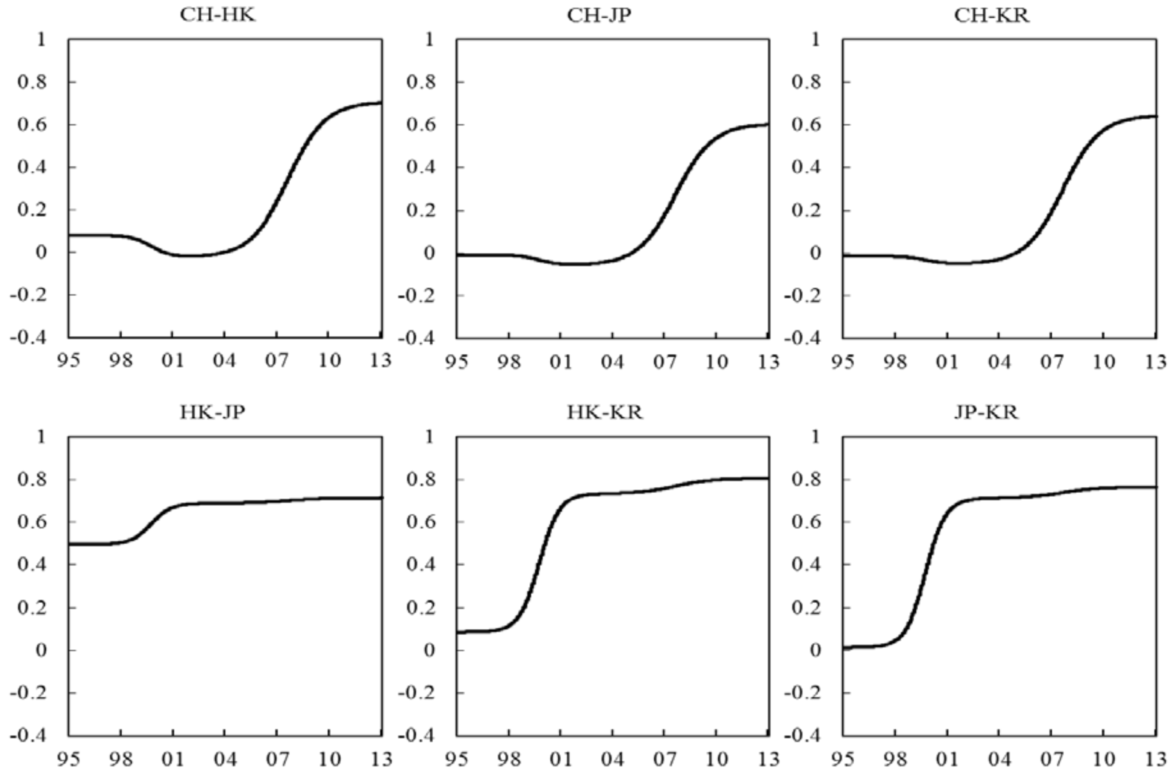

Figure 7: Dynamics of equity return correlation (constrained three-regime model)

Figure 7 plots the dynamics of equity return correlation for each country-pair based on the constrained three-regime STC model with $s_t = t/T$, where T is the sample size.

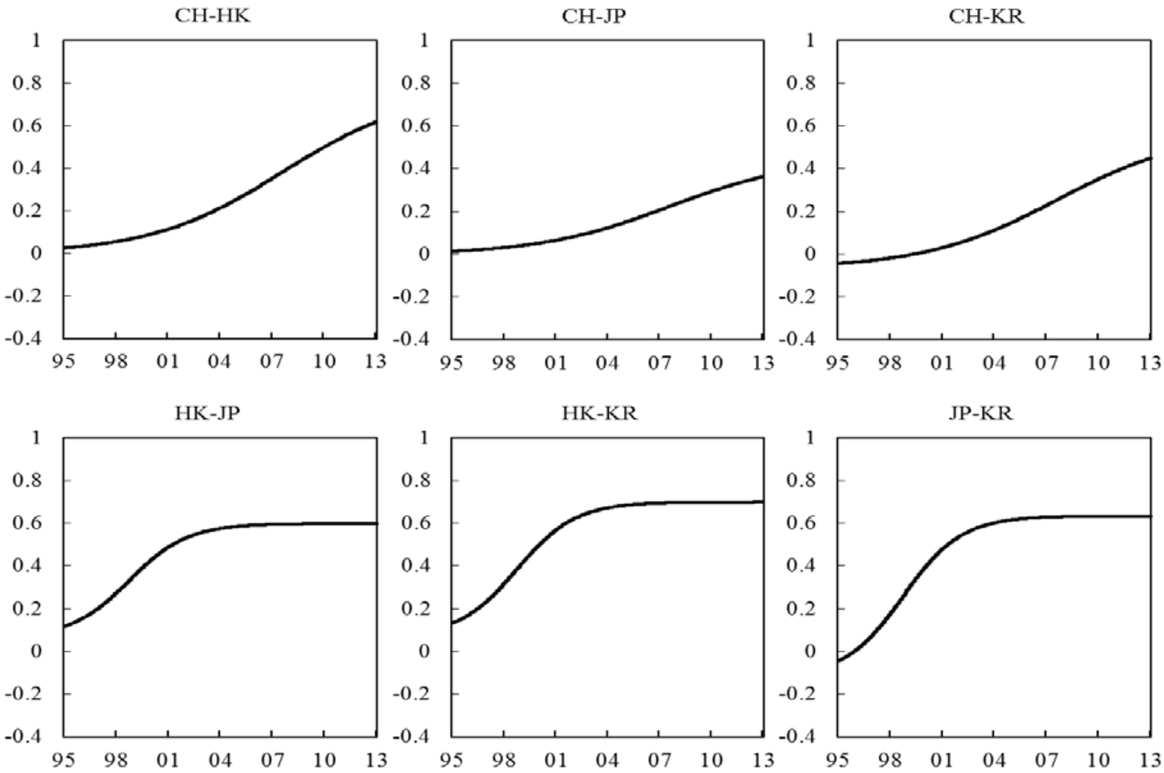

Figure 8: Dynamics of trading-hours return correlation (constrained three-regime model)

Figure 8 plots the dynamics of trading-hours return correlation for each country-pair based on the constrained three-regime STC model with $s_t = t/T$, where T is the sample size.

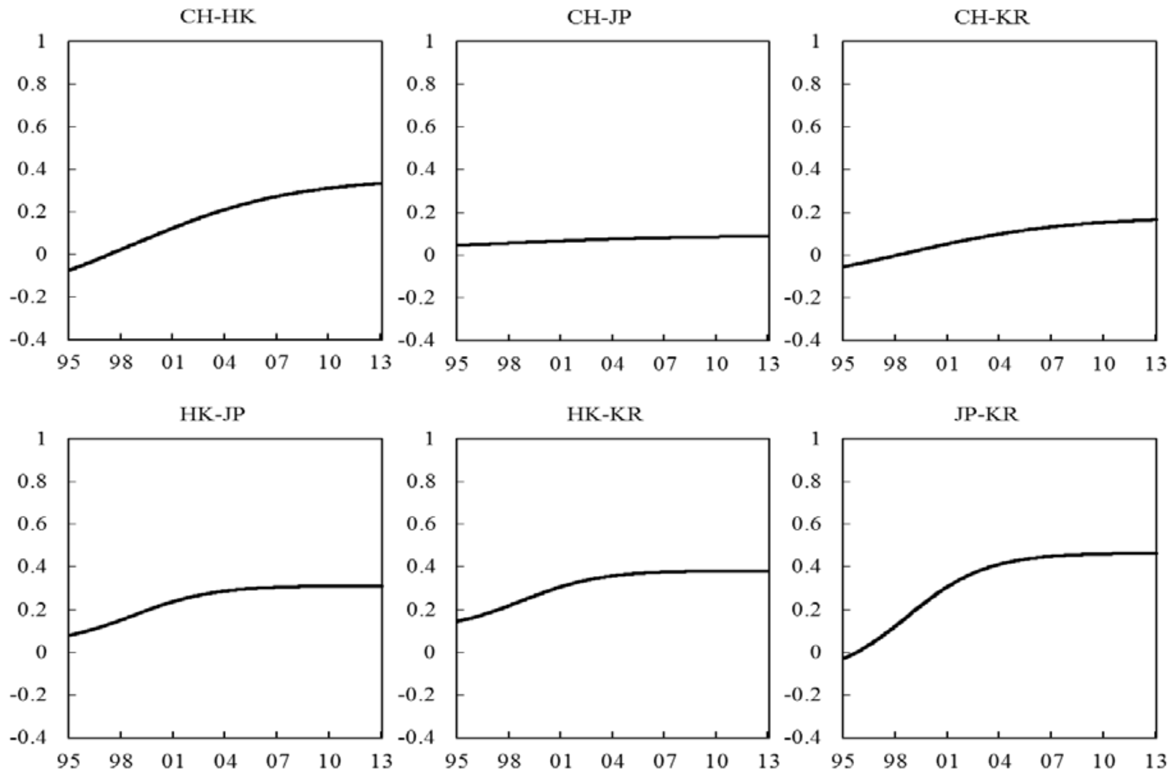

Figure 9: Dynamics of after-trading-hours return correlation (constrained three-regime model)

Figure 9 plots the dynamics of after-trading-hours return correlation for each country-pair based on the constrained three-regime STC model with $s_t = t/T$, where T is the sample size.