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EXPLORING THE DYNAMIC INTERDEPENDENCE AMONG THE EAST ASIAN STOCK MARKETS

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ABSTRACT

Stock market interdependence has strong implication for risk diversification. Recent empirical evidence suggests that correlations between international stock markets increase during period of financial turmoil. This paper investigates the development of stock market integration in East Asia using Dynamic Conditional Correlation GARCH (DCC-GARCH) model of Engle (2002). Weekly data from January 1991 to December 2011 are used in this study. The results show that there are time-varying patterns in both volatility and correlation among the East Asian stock markets. Further, the significant evidence of positive trend in the cross-country conditional correlations is found. Particularly, such correlations increase during the periods of high market volatilities when risk diversification is needed most. These show that the East Asian stock markets are more integrated during the past decade. Therefore, regulators, prospect investors, and fund managers should pay attention in volatility transmission between markets together with the limitations of international diversification during financial crisis.

Keywords: Financial interdependence, East Asian Economies, DCC-GARCH.

INTRODUCTION

During the past few decades, the progress of financial liberalization has been intensifying around the world. Meanwhile, the concept of international diversification of investment in stock markets has spawned a considerable volume of scholarly literatures. Many research papers, e.g. Levy and Sarnat (1970), Solnik (1974), illustrated the diversification benefits derived from the low correlations among the international stock markets. However, once Erb, et al. (1994) and Longin and Solnik (1995) re-examined this issue, they found that the degree of cross-correlation in stock markets were remarkably varying over time. Some researches, e.g. Ang and Bekaert (2002), further found that correlations are intensifying during the period of recession.[3] Consequently, a growing body of literature specifically on the dynamic behavior of stock market interdependence

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[3] See Goetzmann, et al. (2005) for review of literature and historical data on the benefits of international portfolio.

is emerging. Even though dynamic correlations in stock returns are well documented, the existing literatures mainly focus on stock markets in the OCED countries.

Therefore, in this paper, the financial interdependence among the East Asian stock markets is explored because of their increasing role in the global financial market. There are two objectives in this study. First, we explore the dynamic measurement of cross-countries correlation and compute the time-varying cross-countries correlations among the East Asia stock markets. The Dynamic Conditional Correlation (DCC) – GARCH model of Engle (2002) are used in this study followed recent studies, e.g. Jacob and Karagozoglu (2009), Gupta and Donleavy (2009), You and Daigler (2010), to measure dynamic behavior in cross-countries correlations. Second, we check for the presence of long-run trend in degree of these time-varying cross-country correlation series using the trend regressions.

The rest of this paper is organized as follows. The econometric methodology is presented in Section 2. Section 3 provides descriptive statistics while Section 4 reports the empirical results. The last section not only concludes the main findings but also discusses the policy implications.

ECONOMETRIC METHODOLOGY

In this paper, the DCC-GARCH model proposed by Engle (2002) is employed to generate time-varying correlation among the East Asian stock markets. This method follows the multivariate GARCH approach to estimate mean and variance equations for a set of variables using the system of equation. Therefore, conditional variance for each series and covariance between series can be estimated simultaneously. The estimation method of the DCC-GARCH model is briefly discussed as follows.

Let $\boldsymbol{y_t}$ is a vector of *n*-time series variables:$\boldsymbol{y_t} = [y_{1t} \dots y_{nt}]'$,$\boldsymbol{\mu}$is a vector of conditional mean of y_t:$\boldsymbol{\mu} = [\mu_1 \dots \mu_n]'$, and $\mathbf{u}_t$ represent shock variables that can be derived from residuals of mean equation. The mean equation is written as

$$\boldsymbol{y_t} = \boldsymbol{\mu} + \mathbf{u}_t. \tag{1}$$

And the matrix of conditional variance and covariance, $\mathbf{H}_t$, is then defined as:

$$\mathbf{H}_t = \mathbf{D}_t\mathbf{R}_t\mathbf{D}_t, \tag{2}$$

where $\mathbf{D}_t$ is a diagonal matrix of time-varying standard deviations estimated from univariate GARCH models and $\mathbf{R}_t$ is a matrix containing conditional correlation of $\mathbf{u_t}(\rho_{i,j,t})$. Therefore, the $\mathbf{D}_t$ matrix is defined as

$$\mathbf{D}_t = \mathrm{diag}\left(h_{11,t}^{1/2} \ \dots \ h_{nn,t}^{1/2}\right). \tag{3}$$

In this paper, the elements in $\mathbf{D}_t$ is set up as the univariate GARCH(1,1) processes as follow

$$h_{it} = \omega_i + \alpha_i u_{it-1}^2 + \beta_i h_{it-1}. \quad (4)$$

While the conditional correlation matrix, $\mathbf{R}_t$, which consists of the component of DCC structure, is constructed as

$$\mathbf{R}_t = \text{diag}\left(q_{11,t}^{\frac{1}{2}} \dots q_{nn,t}^{\frac{1}{2}}\right) \mathbf{Q}_t \text{diag}\left(q_{11,t}^{\frac{1}{2}} \dots q_{nn,t}^{\frac{1}{2}}\right), \quad (5)$$

where $\mathbf{Q_t}$ is the conditional variance-covariance variables for each series. Specifically,

$$\mathbf{Q_t} = (1 - a - b)\overline{\boldsymbol{Q}} + a\mathbf{u_{t-1}}\mathbf{u'_{t-1}} + b\mathbf{Q_{t-1}} \; ; \; a + b < 1. \quad (6)$$

From above equations, the conditional variance $(q_{i,i,t})$ and covariance $(q_{i,j,t})$ series can be estimated. Consequently, conditional correlations $(\rho_{i,j,t})$ are calculated from the following equation,

$$\rho_{i,j,t} = \frac{q_{i,j,t}}{\sqrt{q_{i,i,t}} \cdot \sqrt{q_{j,j,t}}}. \quad (7)$$

These dynamic conditional correlations $(\rho_{i,j,t})$ are then used as alternative measurements to determine the co-movement between business cycles and provide information on how conditional correlations are changing over time.

DATA

This study covers eight stock markets in East Asia (or ASEAN5+3) — Japan, South Korea, Singapore, Thailand, Malaysia, the Philippines, Indonesia, and China. Moreover, the United States is included in order to represent the major world economy. The stock returns series are calculated from weekly market index during January 1991 to December 2011. All data is collected from Datastream and the stock returns series are plotted in Figure 1.

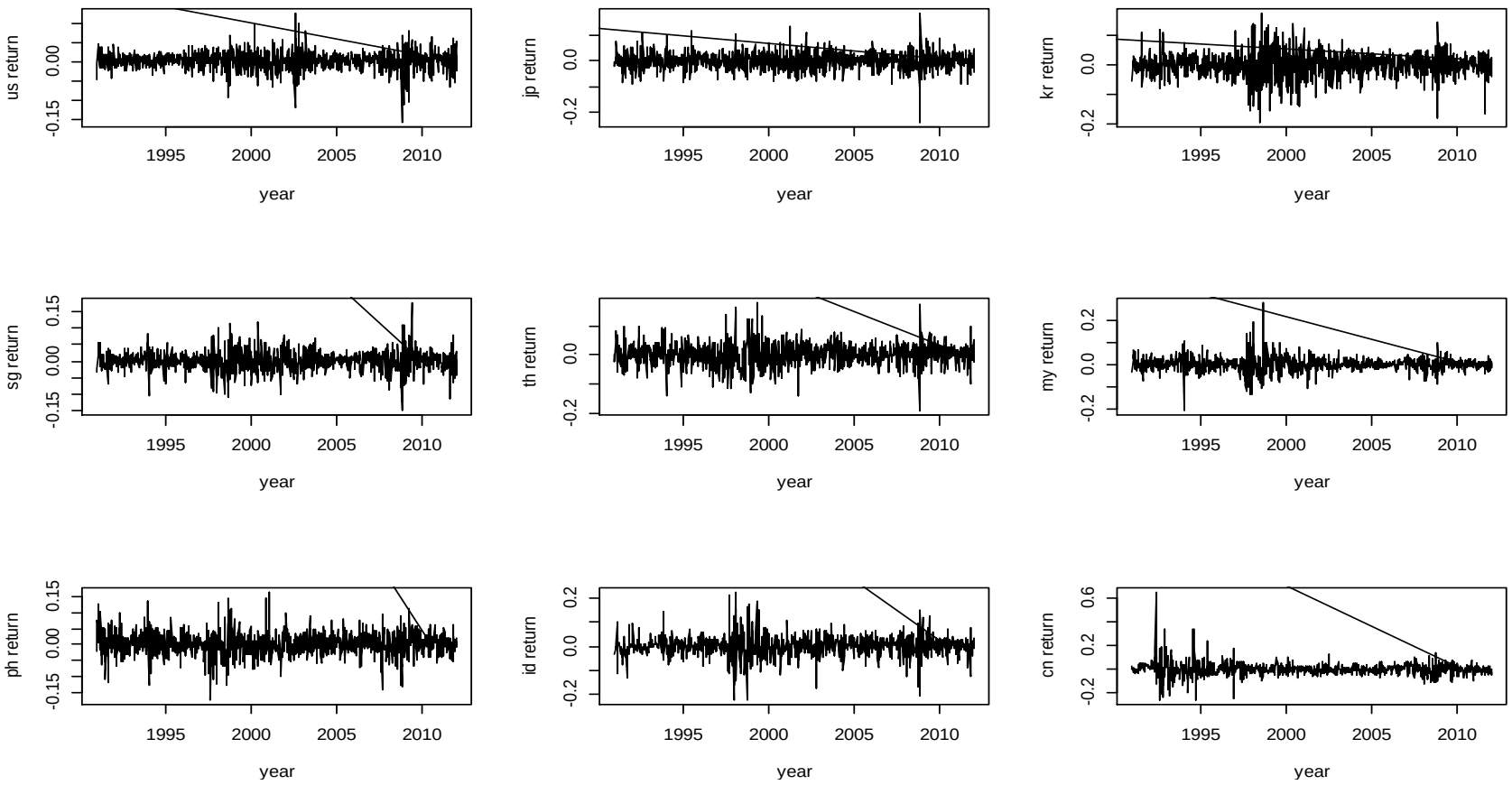


Figure 1 Country Stock Returns

Note: Weekly data; January 1991 – December 2011.
us = United States, jp = Japan, kr = Korea, sg = Singapore, th = Thailand, my = Malaysia, ph = Philippines, id = Indonesia, and cn = China.

Descriptive Statistics

Table 1 presents the statistical properties of the weekly stock returns from eight East Asia countries and the United States. As can be seen, over the sample period, China has the highest weekly stock returns at 0.3 percent while Japan has the negative weekly stock returns at -0.1 percent. Among others, China stock market is the most volatile with standard deviation of 5.5 percent followed by Indonesia and South Korea. The stock returns distribution over time is negatively skewed for all markets except China's. In addition, the stock returns are characterized by a statistically significant kurtosis suggesting that the stock returns have a fatter tail and a higher peak compared with a normal distribution.

Table 1 Descriptive Statistics, Unit Root Test, and Heteroscedasticity Test of the Stock Returns

	Min	Max	Mean	S.D.	Skewness	Excess Kurtosis	ADF-test	$Q^2(k)$
United States	-0.158	0.124	0.001	0.024	-0.569	4.459	-36.555 (0.000)	120.53 (0.000)
Japan	-0.235	0.180	-0.001	0.034	-0.428	4.761	-35.130 (0.000)	360.19 (0.000)
Korea	-0.192	0.173	0.001	0.042	-0.250	2.264	-33.995 (0.000)	165.89 (0.000)
Singapore	-0.150	0.176	0.001	0.030	-0.085	3.178	-32.013 (0.000)	150.56 (0.000)
Thailand	-0.192	0.178	0.000	0.039	-0.031	2.204	-16.125 (0.000)	114.22 (0.000)
Malaysia	-0.209	0.280	0.001	0.032	0.374	9.915	-17.378 (0.000)	157.11 (0.000)
Philippines	-0.171	0.163	0.002	0.036	-0.044	2.310	-31.458 (0.000)	70.508 (0.000)
Indonesia	-0.222	0.226	0.002	0.042	-0.132	5.063	-36.171 (0.000)	227.86 (0.000)
China	-0.259	0.660	0.003	0.055	1.978	24.749	-29.942 (0.000)	47.115 (0.000)

Note: Numbers of lag (k) = 4 for weekly stock returns. The figure in parenthesis represents the *p*-value.

The unit root property is checked by Augmented Dicker Fuller (ADF test). The results show the stock returns series do not contain unit root process. In other words, all series are stationary process. In addition, the Ljung-Box Q statistics of squares residual reveal that there is volatility clustering in every stock returns data. Unlike the stock returns, the conditional heteroscedasticity is found in the United States, Japan, Singapore, Thailand, and China.

Unconditional (Static) Cross-Country Correlations

In this section, the unconditional correlation coefficients are calculated for each pair of countries in our dataset. These statistics provide a basic indicator for financial interdependence. We first compute cross-country correlations using the whole dataset. Next, the whole sample is seperated into 3 sub-sample periods. The first period, 1991 to 1996 is referred to the Asian growth period while the second period, 1997 – 2005, dates the Asian financial crisis. Lastly, the recovering and increasing integration period starts from 2006 onwards.

The unconditional cross-country correlations are then measured in each sub-sample period and they are presented in Tables 2. As can be seen in Tables 2, the unconditional cross-country correlations are not stable over sample period and they are more integrated with each other during the last decade. However, the dynamic nature of cross-country correlation should be considered besides the static one. Therefore, the next section will present the dynamic interdependence in the East Asian which estimated from DCC-GARCH as well as the results of trend regression analysis.

Table 2 Cross-Country Correlations of Stock Returns (Weekly data)

Time Periods	US	JP	KR	SG	TH	MY	PH	ID	CN
	Correlations with United States								
1991 – 1996	**1.000**	0.181	0.065	0.287	0.192	0.287	0.243	0.000	0.012
1997 – 2005	**1.000**	0.328	0.302	0.423	0.292	0.289	0.259	0.111	-0.014
2006 – 2011	**1.000**	0.365	0.561	0.717	0.603	0.567	0.431	0.401	0.263
whole period	**1.000**	0.313	0.334	0.512	0.363	0.336	0.304	0.183	0.066
	Correlations with Japan								
1991 – 1996		**1.000**	0.226	0.220	0.079	0.094	0.053	0.102	0.016
1997 – 2005		**1.000**	0.345	0.242	0.240	0.214	0.128	0.258	0.071
2006 – 2011		**1.000**	0.601	0.383	0.448	0.455	0.275	0.646	0.256
whole period		**1.000**	0.380	0.287	0.260	0.227	0.152	0.341	0.086
	Correlations with Korea								
1991 – 1996			**1.000**	0.189	0.096	0.145	0.007	0.112	-0.053
1997 – 2005			**1.000**	0.331	0.411	0.244	0.234	0.291	-0.028
2006 – 2011			**1.000**	0.616	0.599	0.609	0.384	0.631	0.285
whole period			**1.000**	0.380	0.389	0.280	0.214	0.340	0.025
	Correlations with Singapore								
1991 – 1996				**1.000**	0.531	0.751	0.358	0.113	-0.011
1997 – 2005				**1.000**	0.464	0.473	0.378	0.337	0.058
2006 – 2011				**1.000**	0.682	0.699	0.586	0.473	0.372
whole period				**1.000**	0.534	0.554	0.430	0.342	0.102
	Correlations with Thailand								
1991 – 1996					**1.000**	0.514	0.281	0.199	0.022
1997 – 2005					**1.000**	0.407	0.418	0.357	0.051
2006 – 2011					**1.000**	0.620	0.517	0.550	0.273
whole period					**1.000**	0.464	0.406	0.373	0.077

Table 2 Cross-Country Correlations of Stock Returns (Weekly data) (cont')

Time Periods	US	JP	KR	SG	TH	MY	PH	ID	CN
	Correlations with Malaysia								
1991 – 1996						**1.000**	0.317	0.078	-0.027
1997 – 2005						**1.000**	0.325	0.368	0.049
2006 – 2011						**1.000**	0.562	0.623	0.411
whole period						**1.000**	0.361	0.355	0.064
	Correlations with Philippines								
1991 – 1996							**1.000**	0.094	0.012
1997 – 2005							**1.000**	0.249	0.007
2006 – 2011							**1.000**	0.404	0.336
whole period							**1.000**	0.252	0.079
	Correlations with Indonesia								
1991 – 1996								**1.000**	0.081
1997 – 2005								**1.000**	0.085
2006 – 2011								**1.000**	0.298
whole period								**1.000**	0.110

Notes: The first time period; 1991 – 1996 refers to Asian growth period, the period 1997 – 2005 represents the Asian economic crisis, and the period after 2006 refers to the increasing integration period. Each figure represents the average correlation of weekly stock returns in each sub-period.

EMPIRICAL RESULTS

The DCC-GARCH(1,1) models are estimated using the output growths and stock returns in eight East Asian countries and the United States. The estimation results are shown in Table 3.
The first row reports the mean estimation while the next three rows provide the estimated coefficients of univariate GARCH(1,1) for each of variance equation. The last two rows show the estimation of the DCC(1,1) parameters. Overall, the results show that most of the estimated parametersof the DCC-GARCH models are statistically significant. The conditional cross-countries correlations of stock returns are generated through DCC-GARCH model and they are plotted in Appendix. Obviously, the diagrams reveal that there are significant variations in the cross-country correlation pattern and also significant peaks in some period.

As can be seen in Table 4 and Appendix, the results show the cross-correlation series are unstable and fluctuated over time. In most case, the highest cross-country correlations are found during the period of the Global Financial Crisis in 2007 - 2008. The stock returns in Thailand, Malaysia and Singapore seem to have highest correlation with other countries in the regions. The lowest degree of cross-country correlations is observed in case of China and Indonesia. Considering the change in this correlation though time, we observed that the level in conditional cross-country correlations is increasing, especially after 2005.

Table 3 DCC-GARCH (1,1) Estimations

Coefficients	United States	Japan	Korea	Singapore	Thailand	Malaysia	Philippines	Indonesia	China
	DCC-GARCH (1,1) Estimations of Stock Returns								
μ	0.002 (0.001)	0.000 (0.001)	0.002 (0.001)	0.001 (0.001)	0.002 (0.001)	0.002 (0.001)	0.002 (0.001)	0.004 (0.001)	0.001 (0.001)
ω	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
α	0.118 (0.029)	0.132 (0.054)	0.095 (0.027)	0.124 (0.046)	0.100 (0.043)	0.137 (0.049)	0.114 (0.036)	0.208 (0.142)	0.206 (0.073)
β	0.873 (0.029)	0.696 (0.137)	0.885 (0.031)	0.859 (0.053)	0.869 (0.058)	0.857 (0.052)	0.830 (0.053)	0.709 (0.197)	0.788 (0.064)
a	0.011 (0.002)								
b	0.978 (0.004)								

Note: The standard error of estimated coefficient is in parenthesis

Finally, we address the question that whether the cross-country (conditional) have tendency to increase over time or temporary rise during particular period. The trend regression is then estimated. Specifically, the conditional cross-country correlations ($\hat{\rho}_{i,j,t}$) are used as dependent variable and time trend ($Trend_t$) is used as explanatory variable. Equation (8) represents the trend regression and the estimation results are reported in Table 5.

$$\hat{\rho}_{i,j,t} = \gamma_{i,0} + \gamma_{i,1} Trend_t + v_t, \tag{8}$$

Table 4 Cross-Country Conditional Correlations of Stock Returns

	US	JP	KR	SG	TH	MY	PH	ID	CN
US	**1.000**	0.334	0.320	0.470	0.339	0.383	0.298	0.168	0.082
JP		**1.000**	0.382	0.298	0.241	0.247	0.158	0.302	0.082
KR			**1.000**	0.366	0.344	0.279	0.210	0.313	0.044
SG				**1.000**	0.498	0.578	0.406	0.293	0.117
TH					**1.000**	0.453	0.383	0.311	0.083
MY						**1.000**	0.354	0.314	0.134
PH							**1.000**	0.245	0.079
ID								**1.000**	0.126
CN									**1.000**

Note: The conditional correlations are calculated from DCC-GARCH(1,1) model. Each figure represents the average weekly conditional correlations of stock returns over the whole sample periods, January 1991 – December 2011.

Obviously, Table 5 shows that all of the estimated coefficients in trend regression (except the Malaysia – Singapore pair) are positively significant which indicate that the cross-country correlations of stock returns in ASEAN5+3 and the United States are increasing over time.

Table 5 Trend Regressions for Conditional Correlation of Stock Returns

Cross Correlation	Intercept	Slope	p-value
us – jp	0.268	1.21×10^{-4}	0.000
us – kr	0.172	2.70×10^{-4}	0.000
us – sg	0.348	2.24×10^{-4}	0.000
us – th	0.227	2.04×10^{-4}	0.000
us – my	0.303	1.47×10^{-4}	0.000
us – ph	0.242	1.04×10^{-4}	0.000
us – id	0.065	1.88×10^{-4}	0.000
us – cn	0.002	1.46×10^{-4}	0.000
jp – kr	0.259	2.25×10^{-4}	0.000
jp – sg	0.251	8.56×10^{-5}	0.000
jp – th	0.160	1.47×10^{-4}	0.000
jp – my	0.179	1.25×10^{-4}	0.000
jp – ph	0.111	8.61×10^{-5}	0.000
jp – id	0.176	2.29×10^{-4}	0.000
jp – cn	0.019	1.15×10^{-4}	0.000
kr – sg	0.244	2.24×10^{-4}	0.000
kr – th	0.227	2.14×10^{-4}	0.000
kr – my	0.152	2.33×10^{-4}	0.000
kr – ph	0.105	1.92×10^{-4}	0.000
kr – id	0.183	2.38×10^{-4}	0.000
kr – cn	-0.041	1.55×10^{-4}	0.000
sg – th	0.465	6.14×10^{-5}	0.000
sg – my	0.588	-1.82×10^{-5}	0.028
sg – ph	0.336	1.27×10^{-4}	0.000
sg – id	0.225	1.24×10^{-4}	0.000
sg – cn	0.005	2.05×10^{-4}	0.000
th – my	0.431	4.15×10^{-5}	0.000
th – ph	0.327	1.03×10^{-4}	0.000
th – id	0.247	1.17×10^{-4}	0.000
th – cn	-0.005	1.63×10^{-4}	0.000
my – ph	0.285	1.27×10^{-4}	0.000
my – id	0.195	2.18×10^{-4}	0.000
my – cn	0.011	2.25×10^{-4}	0.000
ph – id	0.184	1.11×10^{-4}	0.000
ph – cn	-0.010	1.63×10^{-4}	0.000
id – cn	0.066	1.09×10^{-4}	0.000

CONCLUSION AND POLICY IMPLICATION

This paper examines the dynamic pattern of co-movement among the stock markets in the East Asian economies. The Dynamic Conditional Correlation (DCC) – GARCH model is used to generate conditional cross-country correlations. Beside from the results that the cross-country correlations of stock return are time-varying, the trend regression analysis shows that the cross-country conditional correlations are increasing over time in every case.

Overall, we conclude the following policy implications from this study:-

i) Financial linkage within the East Asian region and with the global financial market is more linked and is continuously increasing. Therefore, regulators and prospect investors should pay attention in volatility transmission between markets rather than focus only domestic risk.

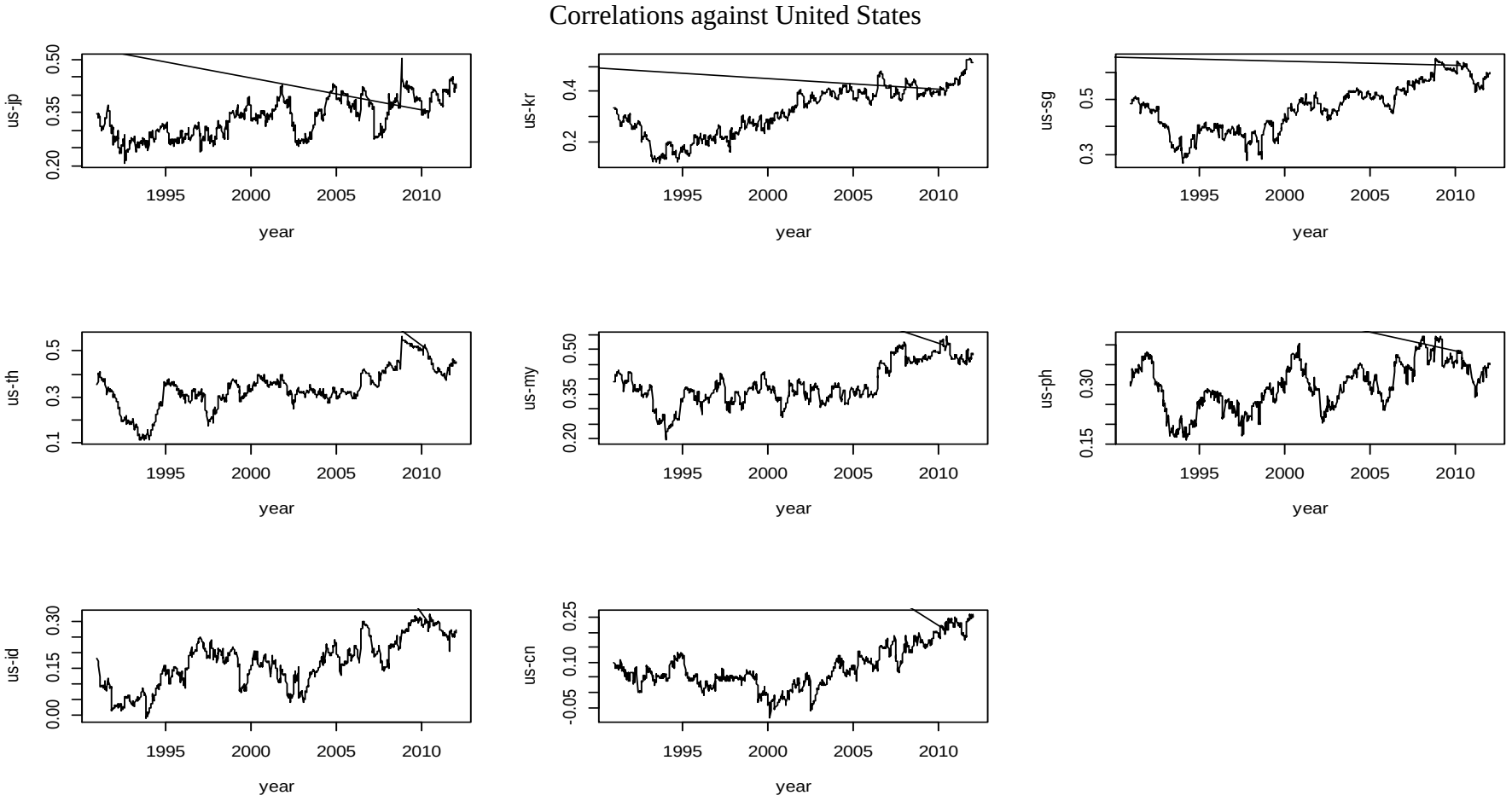
ii) The time-varying correlations usually rise significantly during the economic crisis when risk diversification is needed most. Hence, the East Asian countries should emphasize in preparing the cooperation mechanism, i.e. establishing emergency fund and/or setting up policy coordination with the aim to support or provide regional stability during economic crisis.

iii) The gain from international diversification within and outside the East Asian region decreases over time. Therefore, the domestic factors will be more important to attract capital flow in the region than the diversification gain.

REFERENCES

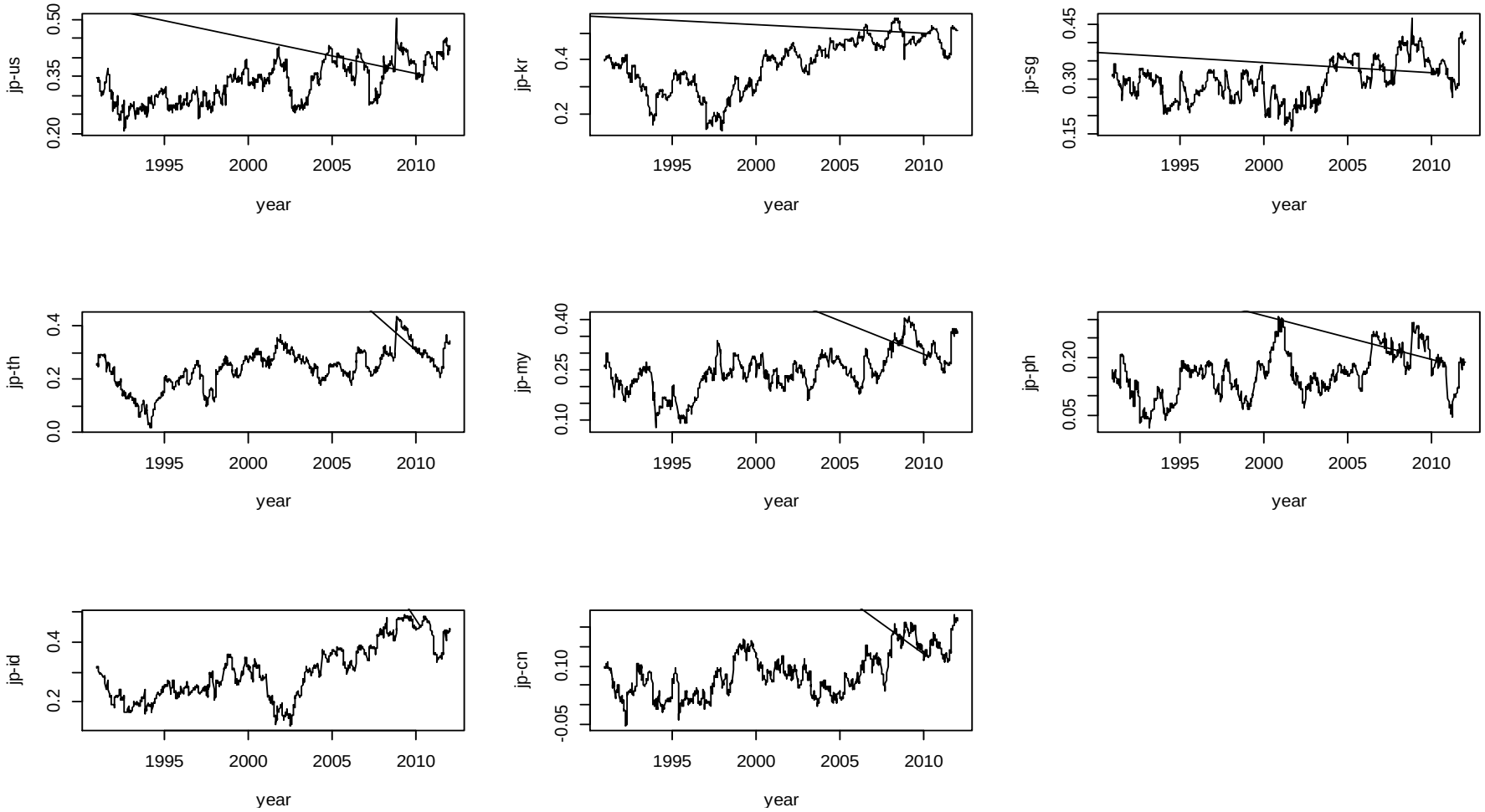
1. Ang, A. & Bekaert, G. (2002) International Asset Allocation with Regime Shifts. *Review of Financial Studies*. 15 (4). 1137-1187.
2. Engle, R. (2002) Dynamic Conditional Correlation: A Simple Class of Multivariate Generalized Autoregressive Conditional Heteroskedasticity Models. *Journal of Business & Economic Statistics*. 20 (3). 339-350.
3. Engle, R. & Colacito (2006) Testing and Valuing Dynamic Correlations for Asset Allocation. *Journal of Business & Economic Statistics*. 24 (2). 238-253.
4. Erb, C.B., Campbell, R.H. & Viskanta, T.E. (1994) Forecasting International Equity Correlations. *Financial Analysts Journal*. 50. 32-45.
5. Gupta, R. & Donleavy, G.D. (2009) Benefits of Diversifying Investment into Emerging Markets with Time-Varying Correlations: An Australian Perspective. *Journal of Multinational Financial Management*. 19. 160-177.
6. Lavey, H. & Sarna, M. (1970) International Diversification of Investment Portfolios. *American Economic Review*. 60(4). 668-675.
7. Longin, F. & Solnik, B. (1995) Is the Correlation in International Equity Return Constant: 1960-1990? *Journal of International Money and Finance*. 14. 3-26.
8. Solnik, B. (1974) Why Not Diversify Internationally? *Financial Analysts Journal*. 30. 48-54.
9. Wang, P. & Moore, T. (2008) Stock Market Integration for the Transition Economies: Time-varying Conditional Correlation Approach. *The Manchester School*. 116-133.
10. Yang, S-Y. (2005) A DCC Analysis of International Stock Market Correlations: The Role of Japan on the Asian Four Tigers. *Applied Financial Economics Letters*. 1. 89-93.
11. You, L. & Daigler, R.T. (2010) Is International Diversification Really Beneficial? *Journal of Banking and Finance*. 34. 163-173.

Appendix Cross-Country Conditional Correlations of Stock Returns



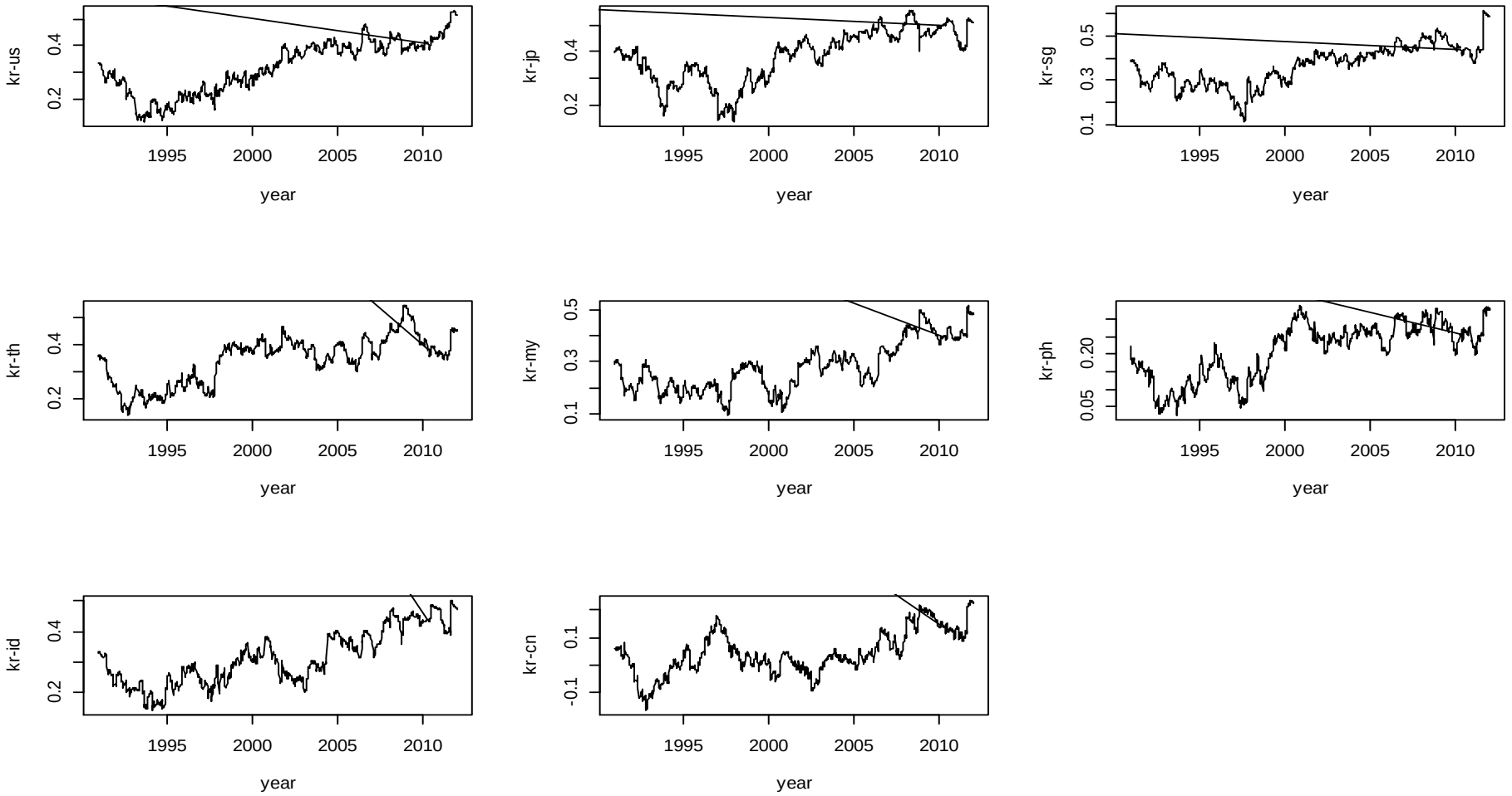
Appendix Cross-Country Conditional Correlations of Stock Returns (cont')

Correlations against Japan



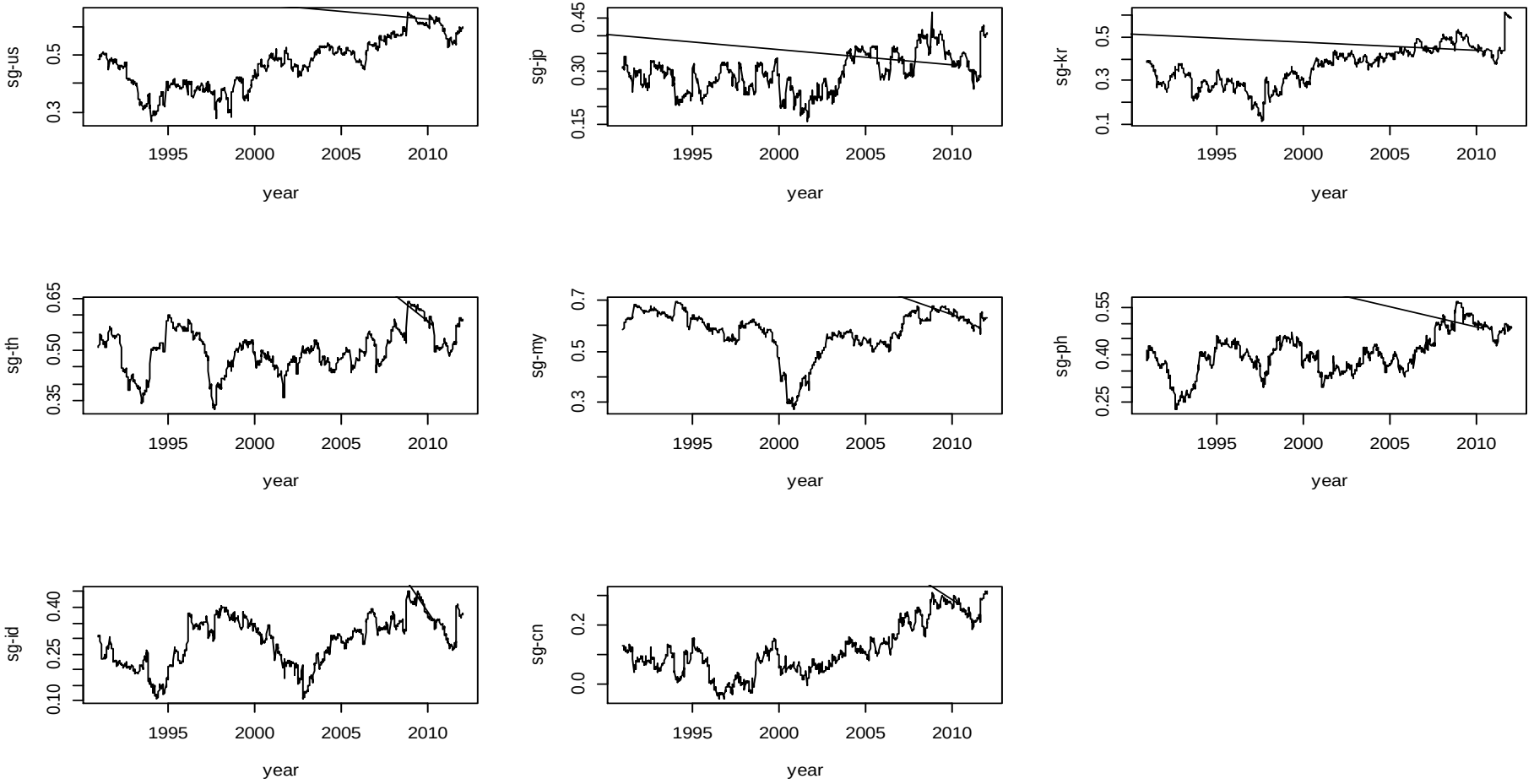
Appendix Cross-Country Conditional Correlations of Stock Returns (cont')

Correlations against Korea

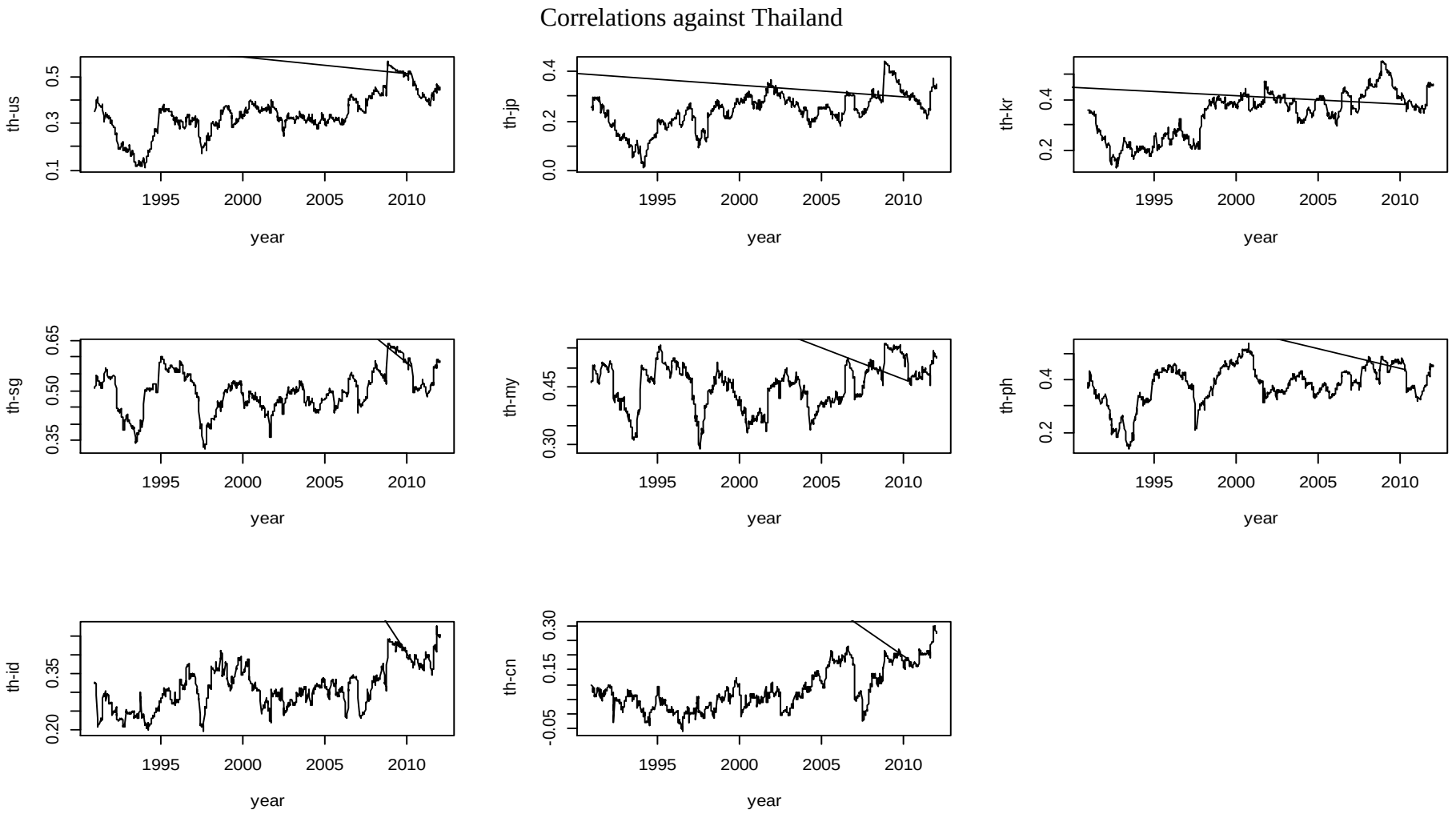


Appendix Cross-Country Conditional Correlations of Stock Returns (cont')

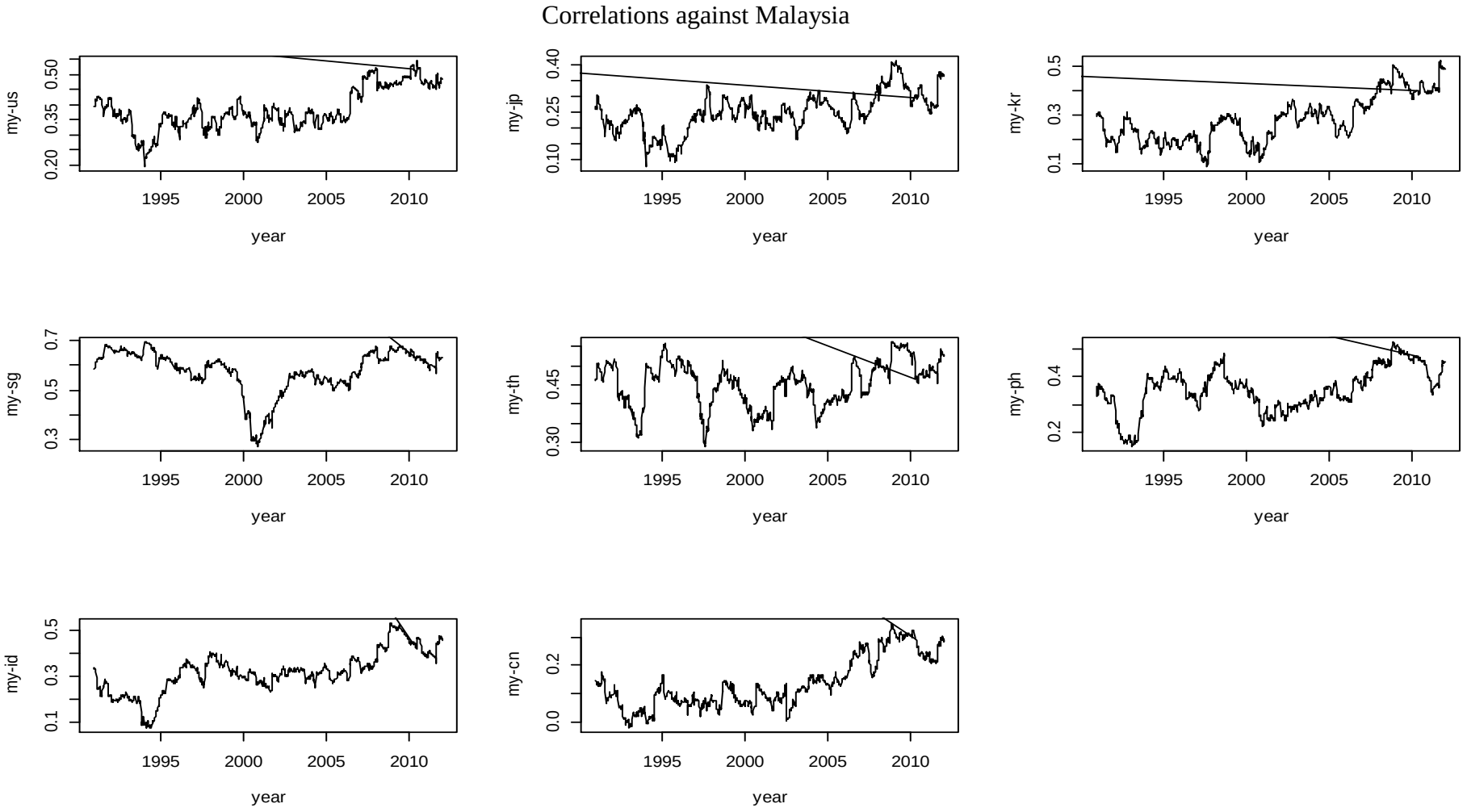
Correlations against Singapore



Appendix Cross-Country Conditional Correlations of Stock Returns (cont')

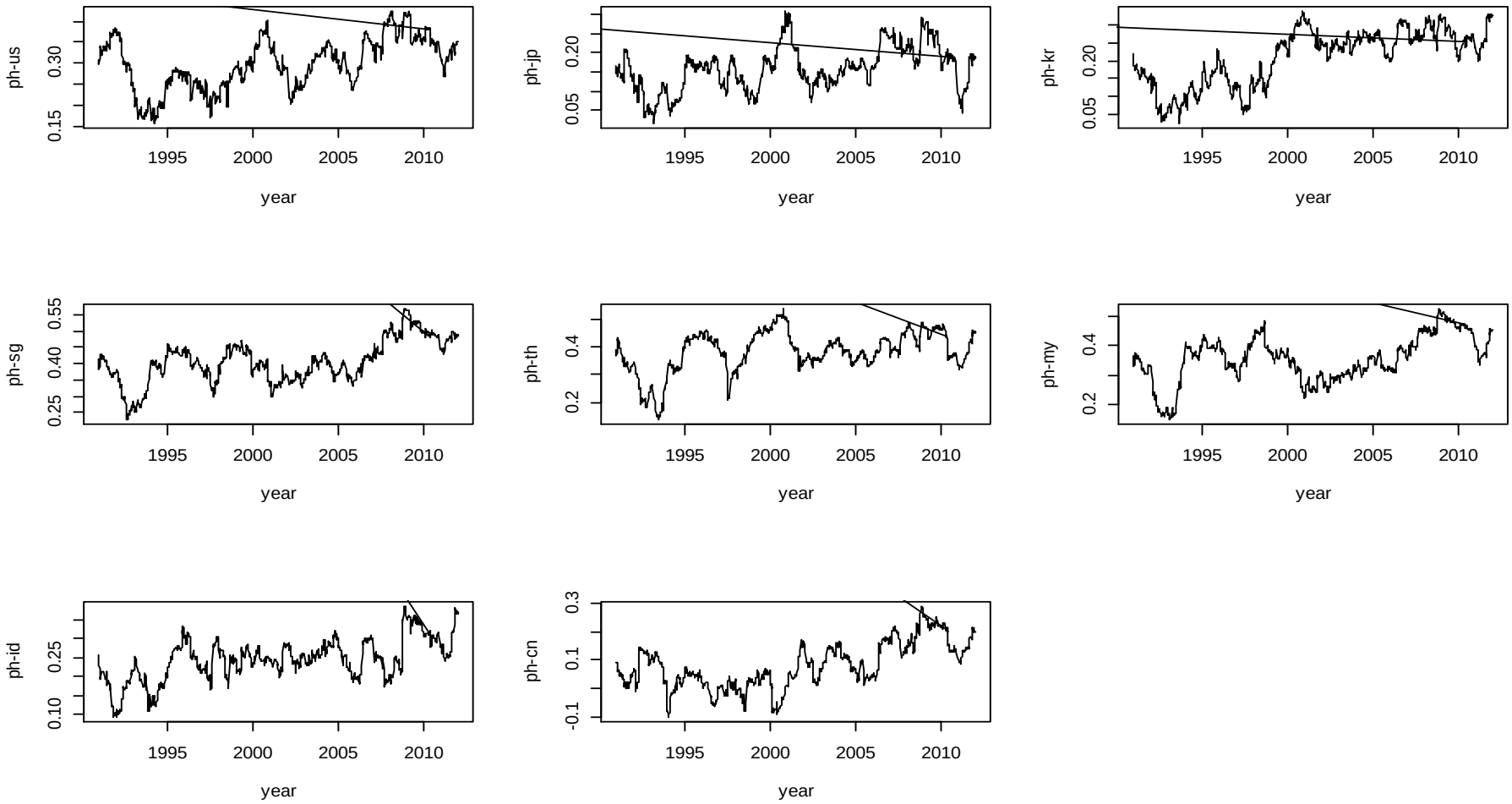


Appendix Cross-Country Conditional Correlations of Stock Returns (cont')



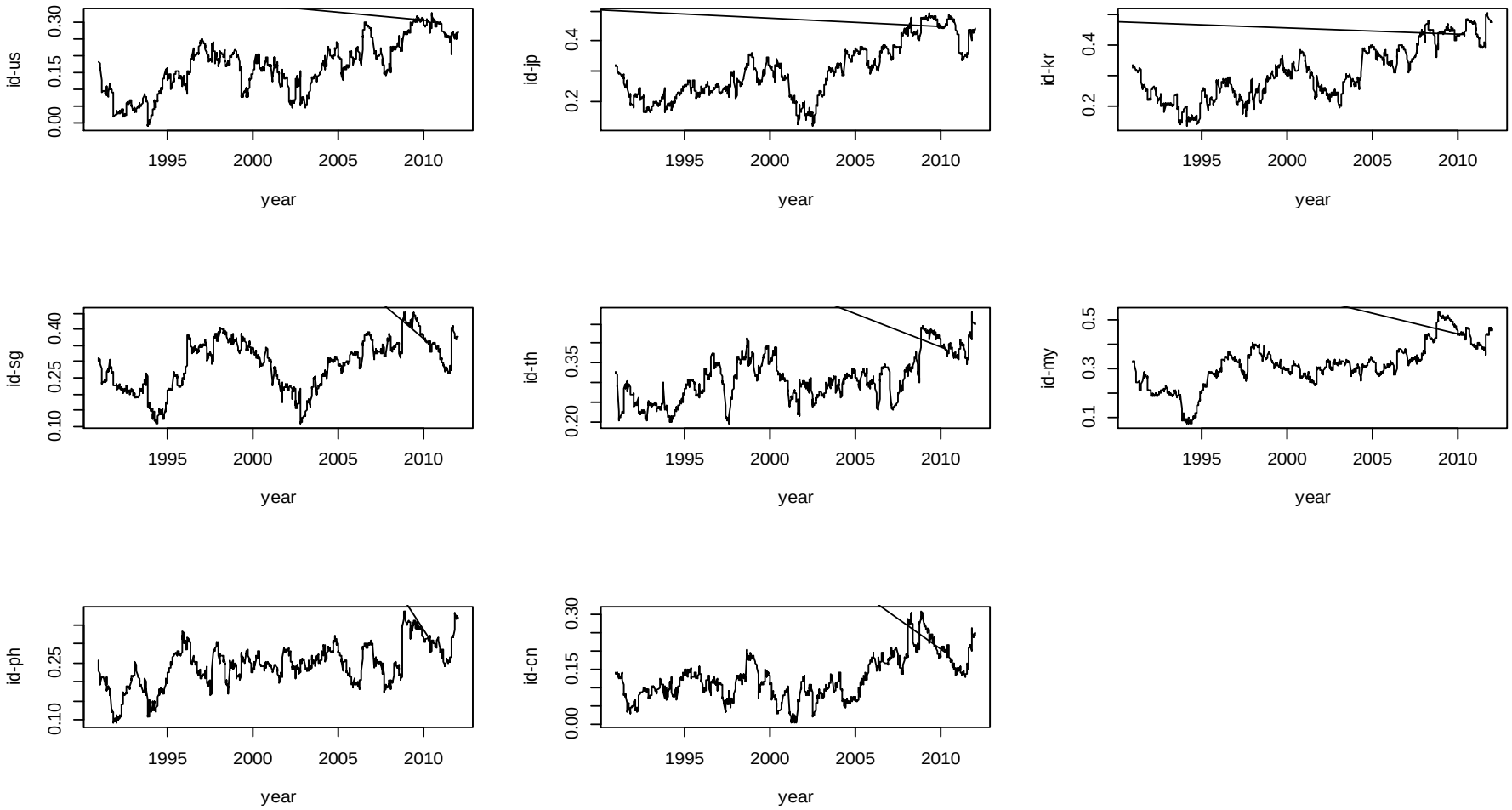
Appendix Cross-Country Conditional Correlations of Stock Returns (cont')

Correlations against Philippines



Appendix Cross-Country Conditional Correlations of Stock Returns (cont')

Correlations against Indonesia



Appendix Cross-Country Conditional Correlations of Stock Returns (cont')

Correlations against China