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## Testing for Contagion during the Asian Crisis

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# **Testing for Contagion during the Asian Crisis**

## **Abstract**

This paper uses a stationary multivariate asymmetric GARCH specification of the international capital asset pricing model to investigate contagion effects across six developed and emerging East Asian markets as well as the US and the World markets around the time of the Asian currency crisis of 1997. After controlling for domestic shocks and spillover effects, the results suggest that the region's equity markets volatility processes display interdependence but little contagion. The results indicate contagion effects only from Thailand to Korea.

## 1. Introduction

The region-wide panic struck first in Thailand before spreading to Malaysia, the Philippines, Indonesia, Korea, and eventually to Taiwan and Hong Kong. During the first year following the inception of the Asian crisis, the currencies of the affected countries depreciated by 35 to 80 percent, reducing wealth substantially. Many analysts argue that the magnitude, severity and geographical reach of the crisis were amplified by contagion effects.<sup>1</sup> However, it is not obvious that the crisis was caused by contagion effects rather than by shared economic weaknesses. Most of the Asian countries that suffered from the crisis shared similar fundamental economic problems. They experienced both external macroeconomic problems (such as fixed exchange rates, high interest rates, excessive borrowing from abroad, and domestic political instability) and internal weaknesses (such as inadequate financial supervisory institutions, antiquated banking practices, and poor investment decisions in the private sector).

The goal of this paper is to assess whether contagion took place. This is important for both investors and policy makers. If contagion occurs it undermines much of the benefits of international diversification. Understanding the source and transmission mechanisms of the crisis are important as policy makers contemplate financial market, institutional, and macro-political reforms to foster a recovery while preventing another crisis.

There are several hypotheses that could explain transferred shocks across countries, and each has different policy implications. For example, Glick and Rose (1998) argue that contagion spreads from countries which are closely tied by international trade linkages to the victim countries. However, the evidence suggests that trade linkages are not sufficient for

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<sup>1</sup> The term contagion refers to herd behavior that occurs when investors pull out of a market because their expectations have been changed by a shock in another market.

explaining the Asian crisis in 1997-1998. For example, Table 1 reports that Thailand's most important export market among Hong Kong, Korea, and Malaysia was Hong Kong, but even Hong Kong never accounted for more than 6.70% of Thailand's exports during 1997-1998. The numbers in Table 1 are too small to account for the large shocks that occurred in Asia.

The explanation of the Asian crisis that we test is that the spread of the crisis was the consequence of herd behavior by investors.<sup>2</sup> The claim that herd behavior was an important contributing factor to the crisis is widely accepted, but to date it has proved difficult to test this claim.<sup>3</sup> The main approach for testing for herd behavior is to test whether the correlations between the returns in the different countries' stock markets rose after the onset of the crisis. If investors in different markets all respond to a shock in one market then we should observe the correlations between the returns in the different countries' stock markets rise after the onset of the crisis.

Forbes and Rigobon (1998,1999) use cross-market correlations to test for stock market contagion from Hong Kong to other countries. They measure the correlation coefficient of the returns in Hong Kong and each other country using a linear ordinary least squares model. However, Forbes and Rigobon (1998) show that conventional correlation coefficients are biased upward, especially during the crisis. Therefore, they propose using "adjusted" correlation coefficients to test for contagion. Their analysis has important

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<sup>2</sup> Calvo and Mendoza (2000) provide an excellent description of herd mentality in a global portfolio diversification framework. They suggest that it is rational for an investor to acquire less information when there are greater opportunities to diversify globally. As a result, there is a more significant impact of "news" on the allocation of investment funds in any particular country. Investors tend to follow the market instead of making their own assessments of each country's fundamentals, perhaps guessing that market portfolios embodied relevant information, or fearing the consequences of disagreeing with the market (Scharfstein and Stein, 1990).

<sup>3</sup> Attempts to assess contagion and investor behavior during the Asian Crisis include Baig and Goldfajn (1998), Forbes and Rigobon (1998, 1999), Glick (1998a, 1998b), Radelet and Sachs (1998), Tan (1998), Manning (1999), Hahn and Mishkin (2000), Ang and Ma (2001), and In et al. (2001).

implications for previous empirical studies because it suggests that high market co-movements during the crisis were simply a continuation of strong cross-market linkages. In other words, there was no contagion – only interdependence. However, it is questionable whether the adjusted correlation coefficient Forbes and Rigobon use is a better measure of contagion effects. One of the crucial assumptions Forbes and Rigobon make is that excess returns are normally distributed, and Longin and Solnik (1998) show that this assumption may result in correlation coefficients that are biased downwards – thus leading to a conclusion of no contagion.

We use cross-market correlations to test for stock market contagion during the 1997 Asian crisis, but we propose a different approach to eliminate the bias in the conventional correlation coefficient. We compute the correlation matrix using time-varying estimates. This conditional correlation coefficient is measured at each point in time so it is automatically adjusted for the bias introduced by the change in market volatility. To compute the time-varying conditional variance we use an asymmetric Generalized Autoregressive Conditional Heteroscedasticity (GARCH) process where volatility responds more to negative shocks than to positive ones.<sup>4</sup> The standard GARCH model allows for the variance to change over time as a function of past errors and the past conditional variance but assumes that volatility responds symmetrically to positive and negative shocks. Several papers (for example, Erb, Harvey, and Viskanta, 1995; Kroner and Ng, 1999; and De Santis and Gerard, 1999) argue that volatility processes increase more following negative shocks than following positive shocks. This is crucial, because during the crisis, when most shocks are negative, the symmetry restriction in GARCH leads to a downward bias in the volatility processes – hence, we use an asymmetric GARCH.

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<sup>4</sup> The estimation method is described in the Appendix.

We find little evidence for contagion. The absence of significant increases in correlations between the different countries' stock markets suggests that co-movement across markets are simply due to their historically close relationships. We find evidence for contagion only from Thailand to Korea.

## **2. Did Contagion Occur in Asia?**

### ***The Data***

The sample covers January 1985 to December 1998. For Hong Kong, Japan, the U.S., and the world, we use the monthly dollar-denominated returns on stock indices supplied by Morgan Stanley Capital International (MSCI). For the emerging markets, Korea, Thailand, and Malaysia, we use the dollar-denominated returns on emerging stock indices from International Financial Corporation (IFC). Emerging market country short-term interest rates are from International Financial Statistics (IFS), and developed countries' short-term interest rates come from the Bank of International Settlement.

### ***The Test***

There is no exact date for the beginning of the crisis. We follow Manning (1999) and take the commencement of the "crisis" to be January 1, 1997. This date is reasonable. According to Radelet and Sachs (1998), in January 1997 Hanbo Steel, a large Korean chaebol, collapsed with debts of six billion US dollars and was soon followed by Sammi Steel and Kia Motors. In early March, Somprasong Land, one of the biggest Thai real estate companies, defaulted on the payments of its foreign debt. By May 1997, the Thai currency was affected by massive

selling, and was finally devalued on July 2. By June 1997, Asian currencies were clearly in “crisis.” The volatility of stock market returns (measured by the standard deviation) in Korea, Malaysia, and Thailand increase dramatically during the crisis: 70% in Korea, 100% in Malaysia, and 65% in Thailand.

We investigate contagion effects by examining how correlations among stock markets change during the crisis. Substantial increases in the correlations after the onset of the crisis are consistent with contagion effects. Panel A in Table 2 reports conventional correlations (covariance divided by the product of the standard deviations) and shows that the correlations between Thailand and all other countries rise after the onset of the crisis. Panel B reports conditional correlations from the asymmetric GARCH process and shows that only the correlation between Thailand and Korea rises substantially. Figures 1-3 present the rolling conditional correlations during the stable period and the crisis period of Thailand and Korea, Thailand and Malaysia, and Thailand and Hong Kong, and lead to the same conclusion. Evidently, using conditional correlation coefficients has a significant impact on the result of the contagion test. In the stable period, results from both correlations (conditional and unconditional) are very similar, but during the crisis the unconditional correlation is substantially greater.

We follow Erb, Harvey, and Viskanta (1998) and investigate one additional measure of cross-sectional correlation. Table 3 reports the highest fraction of countries who all experienced returns in the same direction (either positive or negative) each month. This measure gives a point-wise estimate of cross-sectional correlations. If the ratio equals to one, it implies that all countries in the region move in the same direction. Table 3 suggests that there is a pattern of high cross-sectional correlation in Asia that has little to do with the crisis. Correlations were high before 1995, too: the regional correlation index is about 0.8 in mid



1987 and rises to 1.00 in mid 1994, well before the onset of the crisis. Therefore, the crisis has minimal impact on this index.

### ***Thailand and Korea***

Figure 4 shows that the conditional volatility of shocks in the Thai stock market shock reached about 15% in August 1997 although it had been around 10% throughout the early periods. This number is very striking because it deviated approximately 50% from its pre-crisis conditional volatility. This incident may be seen as an effect of a managed float of the baht in July. Interestingly, the fall in the Thai stock market has a great impact on its correlation with the Korean stock market. Figure 1b shows that after the plunge in the Thai stock market, the correlation rose to over 60% in October 1997. Figure 4 shows that after this rise in correlation, the Korean stock market conditional volatility increased significantly. Conditional volatility in the Korean market stayed at this high level until December, 1998. These circumstances are consistent with a contagion effect because the negative shock in Thailand led to a sharp rise in the correlation and had an enormous impact on the Korean stock market. Thus, we conclude that there was a contagion effect from Thailand to Korea.

### ***Robustness Tests***

In the above estimation we assume that the crisis lasted from January 1, 1997 to December 1998. We repeated the analysis assuming that the crisis started in June 1997 and the main results did not change. There were slight changes in unadjusted correlations results with the new crisis date; Japan, Korea and Malaysia were all victims of contagion effects. However,

results from conditional correlation coefficients still indicate contagion only from Thailand to Korea.

As a second robustness test we consider how an alternative source of contagion affects our results. We follow Forbes and Rigobons (1998,1999) and use the October crash of the Hong Kong market as the event leading to contagion. The period of crisis is October 97 to December 1998 and the period of relatively stability is October 1995 to December 1996. The conclusions are similar to those of Table 2 – the conditional correlations indicate much less contagion. Table 4 shows that unadjusted correlations indicate that there are contagion effects from Hong Kong to several countries, but conditional correlations indicate only slight contagion from Hong Kong to Japan.

Next, because contagion may occur from any country in the region, Table 5 reports the correlation coefficient matrices for every country in the sample using January 1, 1997 as the onset of the crisis. The unadjusted correlations indicate contagion effects in all countries, whereas the adjusted correlations indicate substantial contagion effects only in Korea and Thailand.

### **3. Conclusion**

To assess whether contagion took place during the Asian crisis, we used an international capital market model to examine the spillover effects among crisis countries. We interpret contagion in terms of herd behavior - the basic hypothesis is that if herd behavior was a factor in the crisis, then the correlation between the stock markets of the affected countries should rise during the crisis, even after controlling for the important aspects of own-country risk. A sharp increase in correlation during the crisis period implies that the relationships among countries have moved away from their traditional comovements of fundamentals.

Our tests using unconditional correlation coefficients indicates contagion effects in several markets. However, when conditional correlation coefficients are used, contagion effects occur only between Thailand and Korea. The key results from this paper raise several issues for research on stock market co-movements. Although we did not find a significant increase in stock market co-movement after the onset of the crisis, the co-movements are very high in several countries. Similar experiences during the crisis can be accounted for by a continuation in the high level of interdependence between the various markets.

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## Appendix: The Estimation Procedure

We use an international capital asset pricing model (ICAPM) to describe stock market returns (De Santis and Gerard, 1997), and we use time varying correlation coefficients to determine whether contagion occurred. In the one factor ICAPM, the expected excess return on an asset is proportional to the systematic risk of the asset as measured by its covariance with a market-wide portfolio return:

$$E_{t-1}(r_{it}) = \delta_{m,t-1} \text{cov}_{t-1}(r_{it}, r_{mt} | \mathfrak{I}_{t-1}) \quad (1)$$

where  $r_{it}$  is the nominal excess returns on asset  $i$ ,  $\delta_{m,t-1}$  is the world aggregate risk aversion coefficient,  $r_{mt}$  is the nominal excess return on the world market portfolio between time  $t-1$  and  $t$ , and  $\mathfrak{I}_{t-1}$  is the set of market-wide information variables at the end of time  $t-1$ .

We assume that equation 1 holds for every asset, including the world market portfolio. Let  $R_t$  represent the vector of  $n-1$  risky assets and the world market portfolio, and let  $R_{ft}$  represent the risk free rate of return at time  $t$ . Then equation (1) can be transformed into a conditional ICAPM as follows:

$$R_t - R_{ft}i = \delta_{m,t-1}h_{mt} + \varepsilon_t \quad \text{where } \varepsilon_t | \mathfrak{I}_{t-1} \sim N(0, H_t), \quad (2)$$

where  $i$  is a vector of ones,  $H_t$  is the  $n \times n$  conditional covariance matrix of asset returns (this is used to compute the conditional correlations discussed in the text),  $h_{mt}$  is the  $n$ th column of  $H_t$  and contains the conditional covariance of each asset with the market, and  $\varepsilon_t$  is the vector of shocks ( $\varepsilon_{it}$  is the shock for market index  $i$  and is used to compute the conditional volatility numbers discussed in the text).

We use a GARCH model with asymmetry and feedback in the covariance process, as proposed by De Santis and Gerard (1999). We follow the method De Santis and Gerard (1999) propose to reduce the number of unknown parameters. We assume that the  $\varepsilon_t$  is

covariance stationary. Given this assumption, the process  $H_t$  follows can be computed as a function of model parameters:

$$H_t = C_0 + A' \varepsilon_{t-1} \varepsilon_{t-1}' A + B' * H_{t-1} B + G' \eta_{t-1} \eta_{t-1}' G, \quad (3)$$

where

$$Vec(C_0) = Vec(H_0) [I_m - (A \otimes A)' - (B \otimes B)' - \frac{1}{2}(G \otimes G)'] \quad (4)$$

where  $C_0$  is an  $n \times \frac{n+1}{2}$  matrix of unknown parameters,  $A$ ,  $B$ , and  $G$  are  $n \times n$  matrices of unknown parameters,  $*$  denotes the Hadamard (element by element) product, and  $\eta_{t-1} = \varepsilon_{t-1}$  if  $\varepsilon_{t-1} < 0$  and 0 otherwise. Unfortunately, estimating the system with all seven assets is extremely difficult because there are too many unknown parameters to estimate. Therefore, we assume that the off-diagonal elements in  $A$ ,  $B$ , and  $G$  are zeroes. This implies that the variance and covariance of each asset depends solely on its own negative shocks.

Under the assumption of conditional normality, the log-likelihood function is

$$\ln L(\theta) = -\frac{Tn}{2} \ln(2\pi) - \frac{1}{2} \sum_{t=1}^T \ln |H_t(\theta)| - \frac{1}{2} \sum_{t=1}^T \varepsilon_t(\theta)' H_t(\theta)^{-1} \varepsilon_t(\theta), \quad (5)$$

where  $\theta$  is the vector of unknown parameters in the model. Since the normality assumption is often violated in financial time series, we use the quasi-maximum likelihood (QML) technique proposed by Bollerslev and Woolridge (1992) to estimate the model. The QML procedure yields estimates with properties of maximum likelihood estimators even when the model is mis-specified. Optimization is performed using the BHHH algorithm (Berndt, Hall, Hall, and Hausman, 1974).

# Table 1

## Total Export Shares

The percentage of Thailand's exports that go to selected countries. Table entry is percentage of total exports

[illegible]

**Table 2****Correlation Coefficients**

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Unconditional and average conditional correlations between Thailand and selected countries. The stable period is January 1995 to December 1996, and the crisis period is January 1997 to December 1998.

**Panel A: correlation coefficients are unadjusted and unconditional**

---

Country	Stable period	Crisis period
USA	0.51	0.55
Japan	0.21	0.57
Korea	0.29	0.65
Hong Kong	0.56	0.66
Malaysia	0.57	0.73

---

**Panel B: correlation coefficients are adjusted and conditional**

---

Country	Stable period	Crisis period
USA	0.37	0.30
Japan	0.25	0.26
Korea	0.32	0.54
Hong Kong	0.65	0.52
Malaysia	0.69	0.66

---



**Table 3**  
**Regional Correlation**

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Regional Correlation is the highest fraction of countries who all experienced returns in the same direction (either positive or negative).  
 Countries included are Japan, Korea, Thailand, Hong Kong and Malaysia.  
 Stable period is from January 1995 to December 1996 and  
 the crisis period is from January 1997 to December 1998.

---

	<b>Stable Period</b>		<b>Crisis Period</b>	
<b>Date</b>				
Jan-95	1	Jan-97	0.6	
Feb-95	0.6	Feb-97	0.6	
Mar-95	0.8	Mar-97	1	
Apr-95	0.6	Apr-97	0.6	
May-95	0.6	May-97	0.8	
Jun-95	0.6	Jun-97	0.6	
Jul-95	0.8	Jul-97	0.6	
Aug-95	1	Aug-97	1	
Sep-95	0.6	Sep-97	0.6	
Oct-95	0.6	Oct-97	1	
Nov-95	0.6	Nov-97	1	
Dec-95	0.8	Dec-97	0.8	
Jan-96	0.6	Jan-98	0.6	
Feb-96	0.8	Feb-98	0.8	
Mar-96	0.8	Mar-98	0.8	
Apr-96	1	Apr-98	1	
May-96	0.6	May-98	1	
Jun-96	0.6	Jun-98	0.8	
Jul-96	1	Jul-98	0.6	
Aug-96	0.6	Aug-98	1	
Sep-96	0.8	Sep-98	0.6	
Oct-96	0.6	Oct-98	1	
Nov-96	0.8	Nov-98	0.8	
Dec-96	0.8	Dec-98	0.6	
<b>Average</b>	0.73	<b>Average</b>	0.78	
<b>SD</b>	0.15	<b>SD</b>	0.18	

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**Table 4****Correlation Coefficients**

Unconditional and average conditional correlations between Hong Kong and selected countries. The stable period is October 1995 to December 1996, and the crisis period is October 1997 to December 1998

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**Panel A: correlation coefficients are unadjusted and unconditional**

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Country	Stable period	Crisis period
USA	0.75	0.54
Japan	0.11	0.49
Korea	0.08	0.23
Thailand	0.57	0.69
Malaysia	0.45	0.67

---

**Panel B: correlations are adjusted and conditional**

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Country	Stable period	Crisis period
USA	0.54	0.51
Japan	0.18	0.24
Korea	0.22	0.04
Thailand	0.63	0.53
Malaysia	0.70	0.57

---

**Table 5**

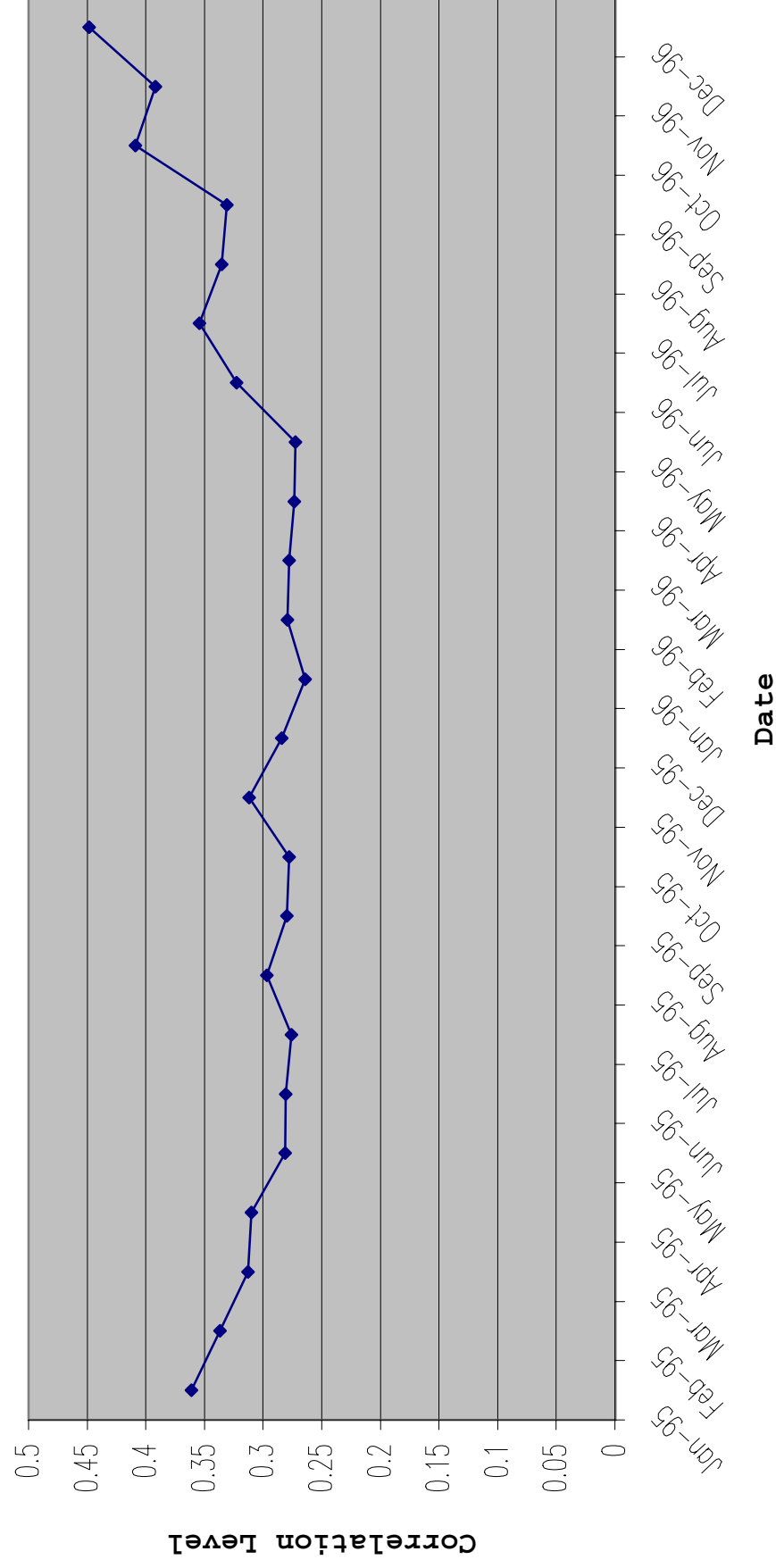
Average Unconditional Correlation Coefficient for residuals shocks in the stable and crisis periods (crisis period in italics). The stable period is January 1995 to December 1996, and the crisis period is January 1997 to December 1998.

	USA	JAPAN	KOREA	THAILAND	HONGKONG	MALAYSIA	WORLD
USA	1	0.33 <i>0.50</i>	0.17 <i>0.30</i>	0.51 <i>0.55</i>	0.47 <i>0.59</i>	0.34 <i>0.59</i>	0.45 <i>0.93</i>
JAPAN		1	0.49 <i>0.65</i>	0.21 <i>0.57</i>	0.06 <i>0.52</i>	0.16 <i>0.40</i>	0.18 <i>0.70</i>
KOREA			1	0.29 <i>0.65</i>	0.15 <i>0.23</i>	0.20 <i>0.34</i>	0.25 <i>0.43</i>
THAILAND				1	0.56 <i>0.66</i>	0.57 <i>0.73</i>	0.58 <i>0.63</i>
HONGKONG					1	0.60 <i>0.64</i>	0.63 <i>0.64</i>
MALAYSIA						1	0.87 <i>0.61</i>
WORLD							1

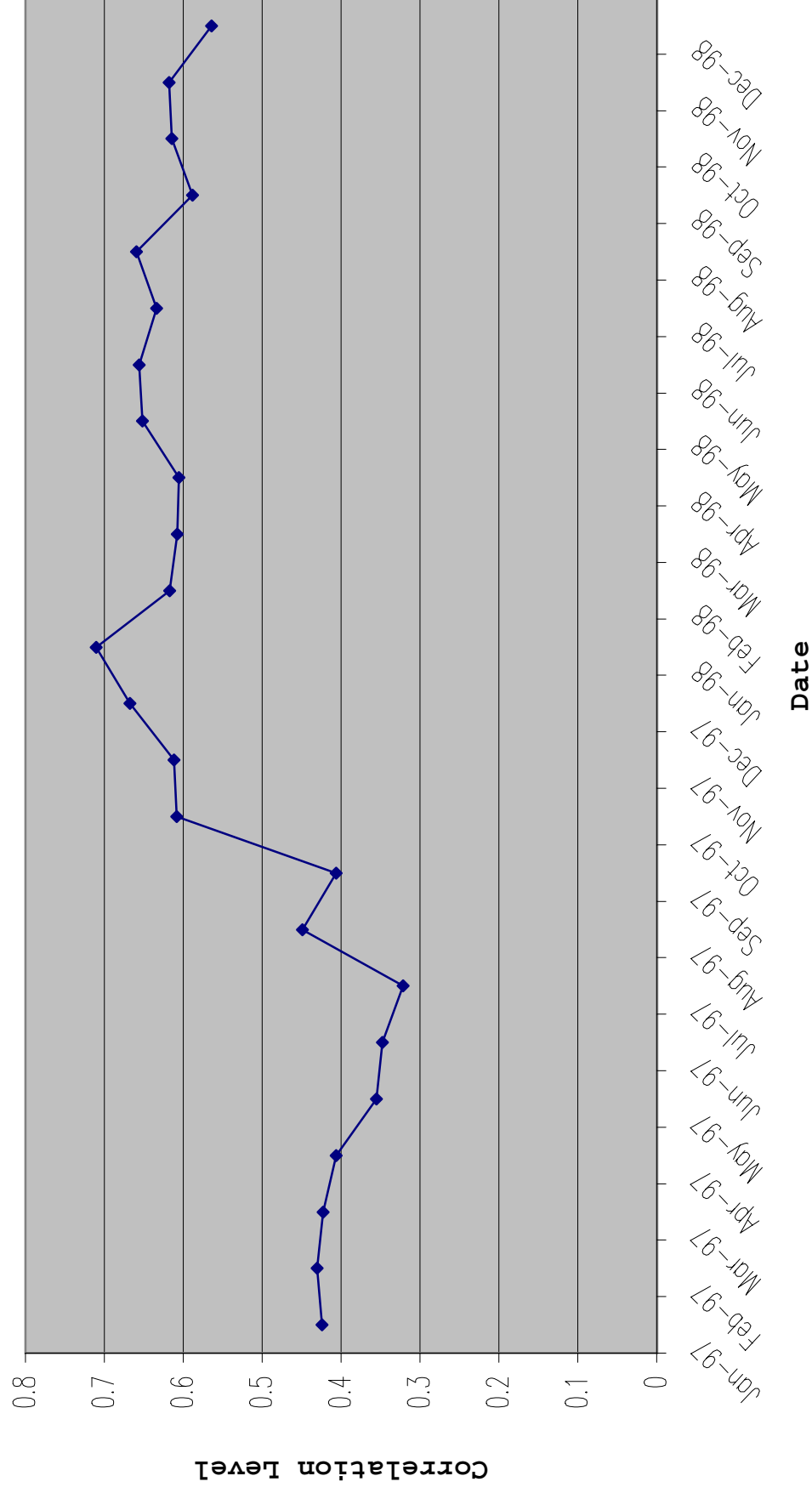
Average Conditional Correlation Coefficient for residuals shocks in the stable and crisis periods (crisis period in italics). The stable period is January 1995 to December 1996, and the crisis period is January 1997 to December 1998.

	USA	JAPAN	KOREA	THAILAND	HONGKONG	MALAYSIA	WORLD
USA	1.00	0.23 <i>0.24</i>	0.19 <i>0.16</i>	0.37 <i>0.30</i>	0.52 <i>0.52</i>	0.51 <i>0.37</i>	0.79 <i>0.78</i>
JAPAN		1.00	0.47 <i>0.31</i>	0.25 <i>0.26</i>	0.18 <i>0.23</i>	0.24 <i>0.23</i>	0.74 <i>0.73</i>
KOREA			1.00	0.32 <i>0.54</i>	0.23 <i>0.10</i>	0.29 <i>0.24</i>	0.37 <i>0.23</i>
THAILAND				1.00	0.65 <i>0.52</i>	0.69 <i>0.66</i>	0.42 <i>0.34</i>
HONGKONG					1.00	0.70 <i>0.58</i>	0.52 <i>0.53</i>
MALAYSIA						1.00	0.53 <i>0.39</i>
WORLD							1.00

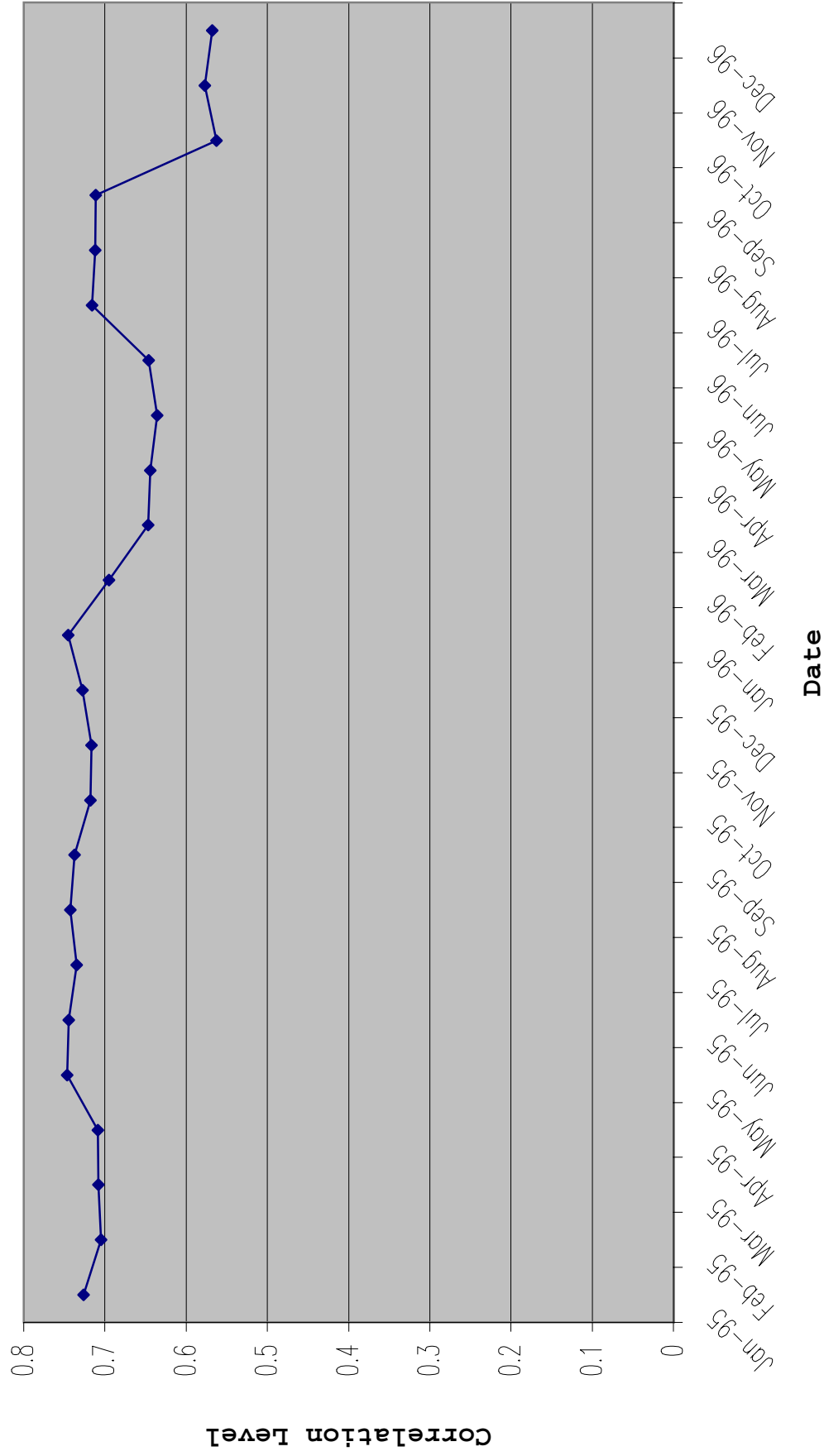
**Figure 1A**  
**Rolling Conditional Correlation between Thailand and Korea**  
**during the Stable Period**



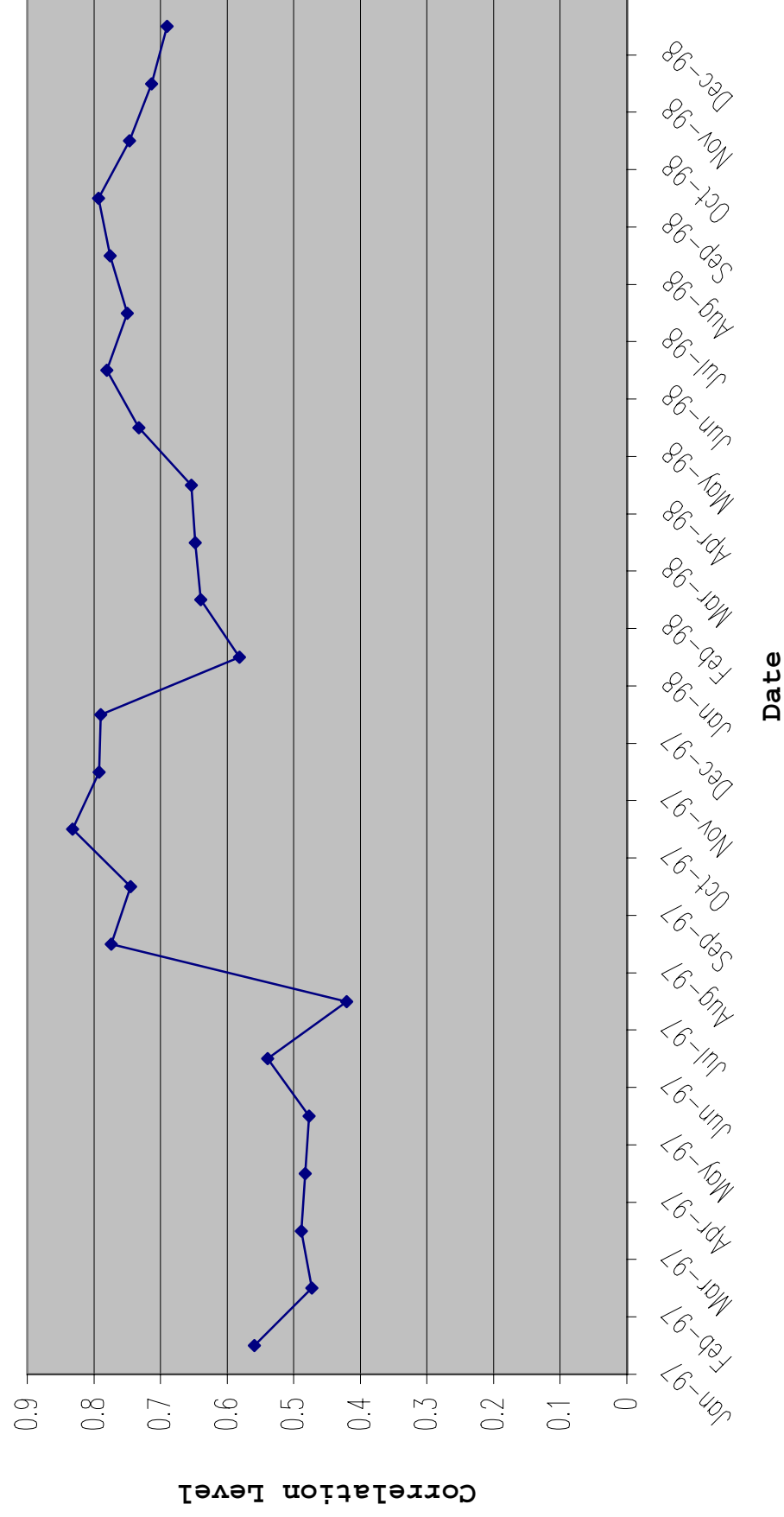
**Figure 1B**  
**Rolling Conditional Correlation between Thailand and**  
**Korea during the Crisis Period**



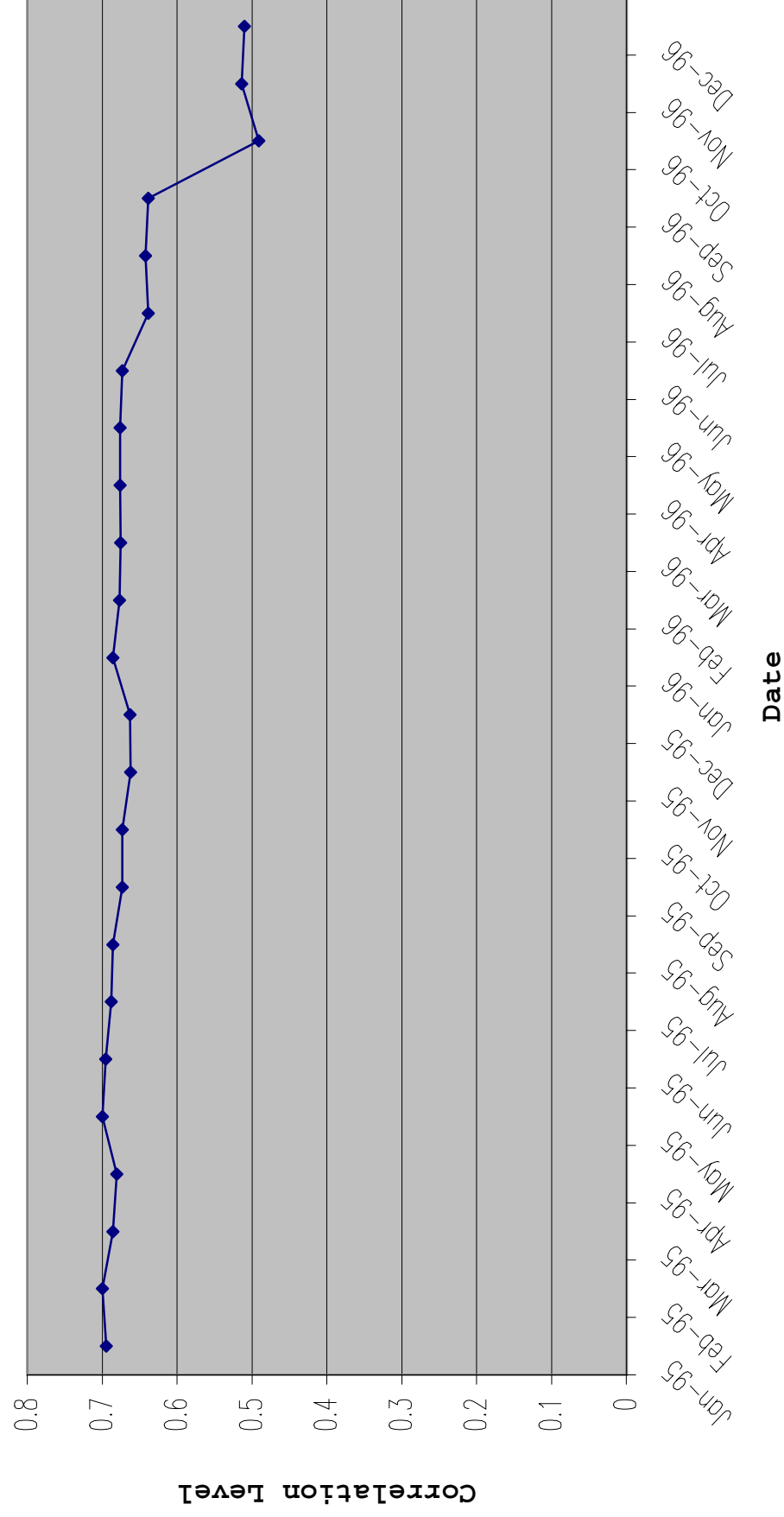
**Figure 2A**  
**Rolling Conditional Correlation between Thailand and**  
**Malaysia during the Stable Period**



**Figure2B**  
**Rolling Conditional Correlation between Thailand and**  
**Malaysia during the Crisis Period**

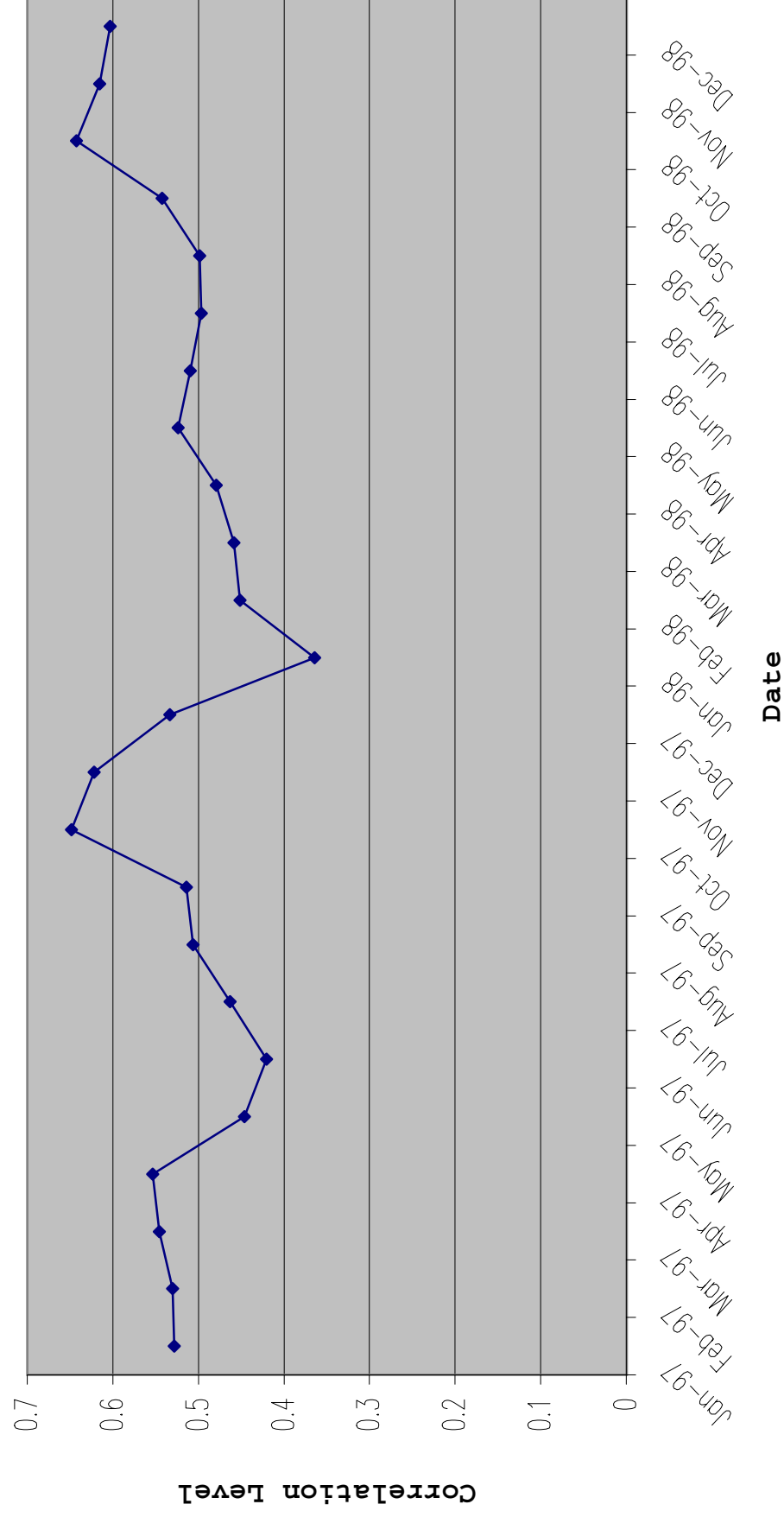


**Figure3A**  
**Rolling Conditional Correlation between Thailand and**  
**Hong Kong during the Stable Period**





**Figure3B**  
**Rolling Conditional Correlation between Thailand and**  
**Hong Kong during the Crisis Period**



**Figure 4**  
**Conditional volatility of Korea vs. Thailand**

