

# CENTRE FOR APPLIED MACROECONOMIC ANALYSIS

The Australian National University



---

**CAMA Working Paper Series**

**February, 2006**

---

## ENDOGENOUS CONTAGION – A PANEL DATA ANALYSIS

**Dirk Baur**

Trinity College Dublin

**Renee Fry**

The Australian National University

---

CAMA Working Paper 9/2006  
<http://cama.anu.edu.au>

# Endogenous Contagion - A Panel Data Analysis

Dirk Baur\* and Renee Fry†

January 2006

## Abstract

This paper proposes a multivariate test for contagion that distinguishes between vulnerability, positive and negative contagion. The model provides a time series of contagion with which the existence, severity and significance of crisis periods can be endogenously determined. Eleven stock markets from the Asian region are analyzed during the Asian crisis, and contagion is significant in four periods. These episodes are split equally between positive and negative movements. Anecdotal evidence is matched to significant contagion, with events surrounding Hong Kong the key drivers.

JEL classification: C10, C51, F36, G14

KEYWORDS: contagion, vulnerability, interdependence, endogenous crisis period, common movements, panel data, fixed time effects

---

\*Corresponding author. Trinity College Dublin and Joint Research Centre, EU Commission Ispra, Italy. Address: Institute for International Integration Studies (IIIS), University of Dublin - Trinity College, College Green, Dublin 2, Ireland. Email: baurd@tcd.ie

†Address: Centre for Applied Macroeconomic Analysis and the Research School of Pacific and Asian Studies, the Australian National University, AUSTRALIA. Email: renee.fry@anu.edu.au. We would like to thank conference participants at the Econometric Society's World Meeting in London 2005, Niels Schulze and Mardi Dungey for useful comments, and Banita Bissoondoyal for sovereign rating agency data.

# 1 Introduction

The incidence of financial crises in recent history has ignited a research agenda into the nature of the spread of financial crises across borders. In particular, the role of ‘contagion’ as a conduit for financial crises has become an important focus. Contagion can be defined as an increase of common movements in a set of financial asset markets in a particular period of time (a crisis period) compared to a benchmark (non-crisis) period (see Baig and Goldfajn, 1999 and Forbes and Rigobon, 2002).<sup>1</sup> These recent methodologies developed to understand contagion emphasize that normal interdependencies between markets need to be accounted for before the spread of crises through contagious channels can be determined. Related to this point is the idea that countries sharing a regional location may be subject to ‘common vulnerabilities’, making them susceptible to shocks from neighboring countries (see Mody and Taylor, 2003).

From the definitions provided by Mody and Taylor, interdependencies arising from common vulnerabilities are explained by economic and financial variables, such as trade linkages, systematic capital flows and banking linkages. Contagion, on the other hand, is the component that is unexplained and unexpected.<sup>2</sup> This view of contagion is equivalent to that of Masson (1999), where monsoonal and spillover effects represent vulnerabilities, and the residual is contagion, and also that of Calvo and Reinhart (1996) and Kaminsky and Reinhart (2000) where there is a distinction between ‘fundamentals’ based contagion and ‘pure’ contagion. Again, fundamentals based contagion is consistent with vulnerabilities, and pure contagion is consistent with our interpretation of contagion.

The focus of this paper is to examine the importance of contagion across a panel of

---

<sup>1</sup>A list of different definitions is provided by the World Bank (<http://www1.worldbank.org/contagion/definitions.html>) and Pericoli and Sbracia (2001).

<sup>2</sup>Examples of mechanisms that theoretical models postulate may cause contagion include herding behavior, information asymmetries and portfolio re-balancing (Calvo and Mendoza, 2000, Kodres and Pritsker, 2002).

eleven equity markets during the Asian financial crisis of 1997 - 1998. A commonly used methodology to analyze contagion in simultaneously falling equity markets over crisis periods is with the correlation coefficient compared to a benchmark (see Forbes and Rigobon, 2002, Karolyi and Stulz, 1996 and Longin and Solnik, 1995). Despite its simplicity, there are several limitations of this approach, including that the correlation coefficient can be biased if heteroscedasticity is present (see Forbes and Rigobon, 2002), tests based on changes in the correlation coefficient can have low power (see Dungey and Zhumabekova, 2001 and Dungey, Fry, González-Hermosillo and Martin, 2005b), the correlation coefficient is inadequate in modeling non-linear phenomena such as contagion (see Bae, Karolyi and Stulz, 2003), only pairs of markets can be analyzed, and correlations between asset markets in a crisis period can actually fall when contagion exists (Corsetti, Pericoli and Sbracia, 2001 and Dungey, Fry, González-Hermosillo and Martin, 2005b).

As the above points allude, several models of contagion have been developed in which a selection of markets are modelled simultaneously. Examples include the vector autoregression (VAR) approach of Favero and Giavazzi (2002), the probit model approach of Eichengreen, Rose and Wyplosz (1995, 1996), the coexceedance approach of Bae, Karolyi and Stulz (2003) and Baur and Schulze (2005), the latent factor approach of Dungey and Martin (2004), Corsetti, Pericoli and Sbracia (2001, 2002) and Bekaert, Harvey and Ng (2005) and the determinant of the change in the covariance matrix (DCC) approach of Rigobon (2003). This paper contributes to the literature on multivariate contagion testing by proposing a panel data model which controls for common vulnerabilities through regional and global equity market indices, and models contagion through the significance of fixed time effects. The fixed time effects are estimates of the time-varying joint movements in Asian equity markets not explained by the regional or global factors. If on any date during the crisis period the fixed time effect reaches a certain threshold, there is evidence of

a large unexplained common factor that is interpreted as contagion.

A key advantage of defining contagion through the importance of fixed time effects and using a large panel data set such as the one in this paper is that a relatively long time varying time series measuring contagion can be extracted. This means that the problem of sample selection bias identified in Pesaran and Pick (2004) is alleviated, as the model is not explicitly identified through the *ex post* selection of a crisis period. The incidence of contagion is endogenously determined, as the period over which the fixed time effects are estimated extends for more than a year, and entirely encompasses the Asian crisis period. Contagion is not necessarily a feature of the entire period in which the fixed time effects are defined, rather its importance is assessed on a daily basis. Further advantages of the approach include that negative and positive contagion can be distinguished, and no assumption about the source country of the crisis needs to be made.

The daily nature of the time series of contagion also means that key events of the crisis period can be analysed to gain some indication of whether these events tend to be associated with contagion. A brief chronology of the events of the financial crisis is presented in Appendix A, and the contagion results are analysed with regard to this chronology. The results indicate that there are four main periods in which contagion is significant, and the break down of these instances are roughly split equally between negative and positive episodes. Matching these periods with ‘news’ as outlined in the chronology suggests that contagion in the Asian crisis was mainly associated with events in Hong Kong.

The remainder of the paper is organized as follows: Section 2 presents the panel data model used to estimate common vulnerabilities and contagion, followed by a description of the data set and the specification of the fixed time effects in Section 3. Section 4 provides the chronology of the crisis, while the estimation results and a discussion on the robustness of the model are contained in Section 5. Section 6 concludes.

## 2 The Econometric Model

The section proposes a panel data model with fixed time effects to analyze contagion across a selection of 11 Asian equity markets. The basic framework is a regression model of the form

$$y_{i,t} = \alpha_i + \gamma_{t^*} + \beta_{i1}f_{\text{regional},t} + \beta_{i2}f_{\text{global},t} + \epsilon_{i,t} \quad (1)$$

where  $y_{i,t}$  is the return of country  $i$  at time  $t$ , and  $f_{\text{regional},t}$  and  $f_{\text{global},t}$  are regional and global factors, respectively. The regional and global factors control for common vulnerabilities with corresponding parameters  $\beta_{i1}$  and  $\beta_{i2}$ .<sup>3</sup> The model contains a constant,  $\alpha_i$ , for each country return vector  $y_i$  and fixed time effects  $\gamma_{t^*}$  which are defined for a period of  $K$  units (e.g. days) through time across all countries  $i$ . The fixed time effects are to be interpreted in comparison to a base period and captures contagion in this model. The error terms of the model are given by  $\epsilon_{i,t}$  and are assumed to be identical and independently distributed (iid) with zero mean and unit variance. The model is estimated as a least-squares dummy variable (LSDV) model (see Greene, 2002, page 565). Since correlation between the fixed time effects and the factors controlling for common vulnerabilities cannot be ruled out, no other specifications like the random-effects model is estimated. Dynamic specifications estimated with first-differences are reported in the robustness analysis section.

The model differentiates between common vulnerabilities and contagion. The former is captured by global and regional factors and the latter by the fixed time effects. Vulnerabilities exist in both the benchmark and crisis period and capture the systematic relationship between the equity markets of each country and the region or the world. It is assumed that the global and regional equity market indices adequately price economic and financial market risks as discussed in Mody and Taylor (2003). The fixed time effects  $\gamma_{t^*}$  capture

---

<sup>3</sup>The model will also be estimated with homogeneous slopes ( $\beta_{i1} = \beta_i$  for  $i = 1, 2$ ).

time-varying joint positive and negative movements across all asset markets that are not explained by the regional or global factors in the period spanning from  $t_0$  until  $t_0 + K$  where  $t^* \in [t_0, t_0 + 1, \dots, t_0 + K]$ ;  $t_0$  denotes the beginning of the potential crisis period window and  $t_0 + K$  its ending. This potential crisis period can span the full sample period but is restricted to a sub-sample for efficiency. If these fixed time effects reach certain thresholds, there is evidence of a large unexplained common factor that is interpreted as contagion. The threshold is considered to be reached if the t-statistic of an estimate of  $\gamma_{t^*}$  is significant at commonly used confidence levels. Although there is a distinction between ‘vulnerability’ (‘interdependence’) and ‘contagion’, it is suspected that some degree of interdependence is a condition for the existence of contagion since a disease can only be transmitted through contact even if this linkage is weak and unobservable.

Panel data have been rarely used in modelling contagion and crises. Most analysis has been applied to crises in currency markets. As far as we are aware, no paper currently defines contagion through the importance of fixed time effects. Fratzscher (1999, 2002) uses a random effects panel model in estimating contagion in currency markets, while numerous other papers draw on the panel methodology of Eichengreen, Rose and Wyplosz (1996). For further examples see Van Rijckeghem and Weder (2000) and Calvo and Reinhart (1996).

The most important advantage of the panel data model in equation (1) is that contagion is endogenously determined and hence avoids the sample selection bias discussed in Pesaran and Pick (2004). The panel database is large enough to be able to specify a lengthy duration over which the fixed time effects can be estimated. The robustness of the estimates of the model to the selection of the length of the fixed time effects window is further discussed in the next section. Assuming that the duration of the fixed time effects entirely encompass the crisis period or a set of potential crisis periods, the exact dates on which contagion is important is determined by the data itself.

It is also worth emphasizing some additional features of the panel data model: First, it is multivariate in nature, and is thus able to model global interdependencies better than the popular correlation based approaches which are bivariate tests (see for example Forbes and Rigobon, 2003 and the discussion in Pesaran and Pick, 2004). Second, the fixed time effects measuring contagion distinguish between joint negative equity market movements and joint positive movements. Intuitively, contagion is problematic when all markets simultaneously plummet, but a simultaneous rise in all markets above that implied by interdependencies may also constitute contagion. In commonly used frameworks for testing of contagion, positive and negative contagion is not distinguished. Third, no assumption as to the country from which contagion is sourced needs to be made. However, the origin of contagion can be tested with the model. Finally, the model can statistically assess the significance of contagion on a daily basis.

### **3 The Data and Fixed Time Effects**

The data set consists of daily (close-to-close) continuously compounded stock index returns of eleven Asian stock markets:<sup>4</sup> China, Hong Kong, India, Indonesia, Japan, Korea, Malaysia, the Philippines, Singapore, Taiwan and Thailand. Vulnerability arising from both world and regional factors is controlled for in the model through the inclusion of the returns of the MSCI World and the MSCI Emerging Markets Free (EMF) Asia indices, respectively. The indices span a time-period of about 7 years from April 30, 1997 until October 22, 2003, for a total of  $T = 1690$  observations. The data is presented in figures 5 - 8 in the Appendix.

Most of the countries in the sample were directly involved in the Asian financial crisis, including Thailand and Hong Kong. Thailand's devaluation and subsequent deprecia-

---

<sup>4</sup>The data is provided by Morgan Stanley Capital International Inc. (MSCI) and can be retrieved under [www.msdata.com](http://www.msdata.com).

tion of the Baht in July 1997, and Hong Kong's speculative attack in October 1998 are considered to be key crisis events. Indonesia, Korea and Malaysia are also crucial crisis countries, while the peg of the Taiwanese dollar was broken just prior to the Hong Kong speculative attack in October 1997. The Philippines also experienced large devaluations. China is included in the sample as it is a large economy in the region, and after the handover of Hong Kong to China in 1997 was presumably increasingly important to Hong Kong in terms of investor expectations of the level of reserves accessible to fend off a speculative attack. Japan and Singapore are included in the sample as they are large financial centers in Asia, and India is particularly interesting for the analysis of contagion since its financial markets are rather isolated.

The fixed time effects are defined to extend from May 1, 1997 to May 29, 1998, a total of 282 observations. The selection of these dates captures the period of the crisis, with additional observations on either side. These dates encompass most others in the literature, and is chosen to end before the build up of pressure in global financial markets prior to the Russian crisis in August 1998. The subsample therefore captures more than ten times the crisis period analyzed in many studies (e.g. see Baig and Goldfajn, 1999 and Forbes and Rigobon, 2002). Dating of crises is always problematic. In particular, determining the end date of a crisis is subjective compared to determining the beginning of a crisis which is usually triggered by an extreme event. However, even the beginning of the Asian crisis is not entirely agreed upon by researchers. Forbes and Rigobon (2002) motivate their selection of the period surrounding the Hong Kong crash as their Asian crisis period, as it was not until this time that media outside of Asia devoted attention to the crisis. Corsetti, Pericoli and Sbracia (2002) and Dungey, Fry and Martin (2003) similarly use the Hong Kong crash as the beginning of the Asian crisis period. Others including Baig and Goldfajn (1999) use the devaluation of the Thai baht as the beginning of the crisis period. A

Table 1: Descriptive statistics of continuously compounded stock index returns: April 30, 1997 to October 22, 2003

Market	Mean	Std. Dev.	Min	Max	Skewness	Kurtosis
China	-0.0008	0.0235	-0.1444	0.1274	0.0838	6.7425
Hong Kong	-0.0001	0.0195	-0.1377	0.1601	0.1772	11.0052
India	0.0001	0.0170	-0.0732	0.0782	-0.1901	5.3206
Indonesia	-0.0008	0.0392	-0.4306	0.2381	-0.9206	20.0683
Japan	-0.0001	0.0159	-0.0716	0.1227	0.3765	6.0370
Korea	0.0002	0.0322	-0.2167	0.2688	0.3021	10.5934
Malaysia	-0.0004	0.0262	-0.3695	0.2568	-0.7011	43.1146
The Philippines	-0.0009	0.0203	-0.1036	0.2197	1.2229	16.8339
Singapore	-0.0003	0.0186	-0.1003	0.1552	0.4859	9.4968
Taiwan	-0.0003	0.0198	-0.1113	0.0739	0.0389	4.9489
Thailand	-0.0005	0.0270	-0.1489	0.1644	0.6949	8.3497

robustness analysis to the dates over which the fixed time effects are defined is presented in Section 5.3.

For completeness, Tables 1 to 3 present descriptive statistics and the unconditional correlation structure for the stock return indices of the eleven countries over the total period spanning April 1997 to October 2003, as well as for the period that the fixed time effects are defined. The important points to note from these tables are that volatility over the period of the fixed time effects is greater than over the entire sample period with the exceptions of Taiwan and India. Furthermore, the unconditional correlation coefficients are all positive, reflecting regional and economic relationships. In most cases, the correlation coefficients are also higher during the fixed time effects period compared to the total sample period.

Table 2: Descriptive statistics of continuously compounded stock index returns over the period of the fixed time effect: May 1, 1997 to May 29, 1998

Market	Mean	Std. Dev.	Min	Max	Skewness	Kurtosis
China	-0.0024	0.0308	-0.1444	0.1274	-0.1025	7.0513
Hong Kong	-0.0017	0.0282	-0.1377	0.1601	0.3537	10.4881
India	-0.0005	0.0138	-0.0434	0.0484	-0.0881	3.8202
Indonesia	-0.0071	0.0680	-0.4306	0.2381	-1.0992	10.6949
Japan	-0.0008	0.0171	-0.0579	0.0785	0.2776	5.1391
Korea	-0.0035	0.0498	-0.2167	0.2688	0.5596	9.1116
Malaysia	-0.0041	0.0402	-0.1262	0.2568	1.1889	10.2783
The Philippines	-0.0023	0.0278	-0.1036	0.1320	0.3466	5.7616
Singapore	-0.0024	0.0265	-0.1003	0.1552	0.8462	9.4739
Taiwan	-0.0012	0.0190	-0.1113	0.0627	-0.6947	7.4313
Thailand	-0.0044	0.0407	-0.1489	0.1644	0.7216	5.7182

Table 3: Correlation matrix of continuously compounded stock index returns: April 30, 1997 to October 22, 2003

China	1.0000	0.6194	0.1935	0.2637	0.2876	0.2749	0.2738	0.2917	0.4449	0.2665	0.3215
Hong Kong	0.6909	1.0000	0.2245	0.3372	0.3487	0.3161	0.3092	0.3362	0.6046	0.2948	0.3757
India	0.1692	0.2408	1.0000	0.1090	0.1552	0.2051	0.1195	0.1301	0.1950	0.1372	0.1829
Indonesia	0.3402	0.4083	0.1313	1.0000	0.1992	0.1742	0.3281	0.3458	0.4293	0.1790	0.3689
Japan	0.2352	0.3424	0.0737	0.1942	1.0000	0.2822	0.2162	0.2110	0.3782	0.2394	0.2599
Korea	0.0611	0.0805	0.1416	0.1088	0.1121	1.0000	0.2024	0.2070	0.2961	0.2680	0.3230
Malaysia	0.3220	0.3788	0.1614	0.4977	0.2277	0.2092	1.0000	0.2484	0.3864	0.1770	0.3558
The Philippines	0.3835	0.4512	0.1644	0.4596	0.1724	0.1429	0.4538	1.0000	0.4079	0.1746	0.3756
Singapore	0.5372	0.6691	0.2051	0.5806	0.3286	0.0635	0.5959	0.6180	1.0000	0.3190	0.4638
Taiwan	0.3302	0.3344	0.0750	0.2488	0.2314	0.0845	0.3229	0.2848	0.3765	1.0000	0.2482
Thailand	0.2819	0.3211	0.2208	0.3980	0.1866	0.2176	0.4819	0.4544	0.4701	0.3066	1.0000

upper triangular matrix is the correlation of the full sample period, lower triangular matrix is the correlation for the fixed effects period

## 4 A Chronology of the Crisis

The daily time series of the fixed time effects makes it pertinent to examine the events surrounding the dates where a value of a fixed time effect indicates evidence of significant contagion to try to determine likely triggers or explanations of contagion. With this aim in mind, a chronology of the Asian crisis is constructed over the period that the fixed time effects are defined using events that *a priori* may be expected to contribute to unanticipated volatility in the regions equity markets. This chronology is contained in Appendix A. The empirical results for contagion of the next section are discussed in line with this chronology. The approach is similar to those whereby authors construct dummy variables to capture news events and then include them as explanatory variables in a model of contagion such as Baig and Goldfajn (1999), Kaminsky and Schmukler (1999b) and Debelle and Ellis (2005).

The chronology is classified into four types of events. The first is key crisis events which essentially encompasses the suspension or closure of financial entities, currency devaluations or large widening of currency trading bands, government packages to address the crisis, and other coordinated international responses such as the roll over of Korea's private short term debt by international creditors. The second consists of events relating to the involvement of the IMF in the crisis. This includes requests for IMF assistance, the announcement of rescue packages, disbursements of funds, countries' letters of intent as submitted to the IMF as well as progress reviews. The third category captures major political events such as change in government and the resignation of key ministers/bureaucrats, while the fourth documents sovereign ratings changes by Moody's Investors Service and Standard and Poor's (see Moody's Investors Service, 2002, and Standard and Poor's, 2004, for details). The chronology contains 31 key events, 30 IMF policy events, 13 political events and 51 rating events.

Several useful chronologies documenting the crisis in Asia are available. The ones drawn upon in this paper include Bank for International Settlements (1998), Roubini (1998), the Washington Post (1998), the BBC (1998), IMF (2000, 1999), Lindgren, Balino, Enoch, Gulde, Quintyn and Teo (1999) and Kaminsky and Schmukler (1999a,b). More country specific chronologies are documented in Cameron (1999), Soesastro and Bastri (1998) and IMF (1998) for Indonesia, Ministry of Finance (1999), Warr (2001) and Siamwalla (2001) for Thailand, Athukorala (2001) and Jomo (1998) for Malaysia, and Chopra, Kang, Karasulu, Liang, Ma and Richards (2001) for Korea.

## **5 Empirical Results**

This section presents the results for the estimation of the model of vulnerability and contagion specified in equation (1). Estimation results of the parameters of vulnerability are given in table 4. Results of the fixed time effects estimates are shown in tables 5 and 6. These tables contain the date, the estimated coefficients and their corresponding t-values. The bottom panel of the table reports an  $R^2$  of 31.46%, and a F-statistic of 18.26 testing the joint significance of the exogenous variables and the fixed time effects. The hypothesis of 'no significance' is clearly rejected.

### **5.1 Vulnerabilities**

The results show that vulnerabilities are generally important for all countries of the sample. The world index which captures global vulnerabilities has a positive effect and is significant for the countries with the most developed financial markets, namely Hong Kong, Singapore and Japan. The parameter estimates for these countries range between 0.11 and 0.37, with t-values between 2.2 and 7.2. World returns are almost significant for Korea, who became a member of the OECD prior to the Asian crisis in 1996, with a t-value of

Table 4: Estimation results of equation (1): regional and global vulnerabilities

<b>Regional factor (EMF Asia)</b>	$\hat{\beta}_{i1}$	t-value
China	0.6901	20.1861
Hong Kong	0.5667	16.5779
India	0.4079	11.9319
Indonesia	1.0655	31.1679
Japan	0.2722	7.9641
Korea	1.3351	39.0544
Malaysia	0.8327	24.3589
The Philippines	0.4578	13.3917
Singapore	0.5778	16.9037
Taiwan	0.7753	22.6808
Thailand	0.8988	26.2923
<b>Global factor (MSCI World)</b>	$\hat{\beta}_{i2}$	t-value
China	0.1110	2.1519
Hong Kong	0.3480	6.7478
India	0.0090	0.1746
Indonesia	-0.0578	-1.1208
Japan	0.3737	7.2442
Korea	0.0828	1.6055
Malaysia	-0.0792	-1.5357
The Philippines	0.0302	0.5864
Singapore	0.2877	5.5769
Taiwan	-0.0624	-1.2093
Thailand	0.0510	0.9881
$R^2$ (unrestricted)	0.3146	
$R^2$ (restricted)	0.2927	
F	18.2581	(<.0001)

The p-value of the F-statistic is given in parenthesis.

Table 5: Estimation results of equation (1): Fixed time effect and contagion

$k$	Date	$\hat{\gamma}_{t^*+k}$	t-value	$k$	Date	$\hat{\gamma}_{t^*+k}$	t-value	$k$	Date	$\hat{\gamma}_{t^*+k}$	t-value
1	5/1/1997	0.0023	0.3769	51	7/10/1997	-0.0001	-0.0235	101	9/18/1997	-0.0025	-0.4046
2	5/2/1997	0	-0.0057	52	7/11/1997	-0.0013	-0.2108	102	9/19/1997	0.0001	0.0202
3	5/5/1997	0.0057	0.9167	53	7/14/1997	0.0024	0.3951	103	9/22/1997	-0.0036	-0.5869
4	5/6/1997	0.0072	1.1591	54	7/15/1997	0.0026	0.4282	104	9/23/1997	-0.0041	-0.658
5	5/7/1997	-0.0025	-0.3971	55	7/16/1997	0.0035	0.5731	105	9/24/1997	0.0058	0.9458
6	5/8/1997	-0.0023	-0.3764	56	7/17/1997	0.0025	0.4073	106	9/25/1997	0.0112	1.8079
7	5/9/1997	0.0021	0.339	57	7/18/1997	0.007	1.1296	107	9/26/1997	-0.0065	-1.0508
8	5/12/1997	0.0075	1.2071	58	7/21/1997	-0.0052	-0.8505	108	9/29/1997	-0.0069	-1.1105
9	5/13/1997	0.0009	0.1508	59	7/22/1997	0.0001	0.0088	109	9/30/1997	0.0033	0.5289
10	5/14/1997	-0.002	-0.3321	60	7/23/1997	-0.0004	-0.0671	110	10/1/1997	0.0013	0.2039
11	5/15/1997	-0.0019	-0.3076	61	7/24/1997	-0.0031	-0.5102	111	10/2/1997	-0.0005	-0.087
12	5/16/1997	-0.0048	-0.7797	62	7/25/1997	0	0.0009	112	10/3/1997	-0.006	-0.9735
13	5/19/1997	0.002	0.3298	63	7/28/1997	0.0008	0.1353	113	10/6/1997	-0.0057	-0.927
14	5/20/1997	0.0054	0.8718	64	7/29/1997	-0.0015	-0.2353	114	10/7/1997	-0.0082	-1.3281
15	5/21/1997	-0.0007	-0.121	65	7/30/1997	-0.0002	-0.0376	115	10/8/1997	-0.0045	-0.7236
16	5/22/1997	-0.0083	-1.3448	66	7/31/1997	0.0081	1.3174	116	10/9/1997	-0.003	-0.4898
17	5/23/1997	0.0016	0.253	67	8/1/1997	0.0006	0.1052	117	10/10/1997	0.006	0.978
18	5/26/1997	-0.0011	-0.1779	68	8/4/1997	0.0034	0.5572	118	10/13/1997	-0.004	-0.6505
19	5/27/1997	0.0035	0.571	69	8/5/1997	0.0045	0.7264	119	10/14/1997	-0.0059	-0.9545
20	5/28/1997	0.0015	0.2366	70	8/6/1997	0.0017	0.2833	120	10/15/1997	-0.0031	-0.5072
21	5/29/1997	-0.0015	-0.2371	71	8/7/1997	0.0027	0.4327	121	10/16/1997	0.0051	0.8182
22	5/30/1997	0.0035	0.5693	72	8/8/1997	0.0014	0.2343	122	10/17/1997	0.0106	1.7174
23	6/2/1997	0.0044	0.7073	73	8/11/1997	-0.0042	-0.673	123	10/20/1997	-0.0062	-0.9942
24	6/3/1997	-0.0014	-0.2204	74	8/12/1997	0.0027	0.4421	124	10/21/1997	-0.0148	-2.3931
25	6/4/1997	0.0018	0.2892	75	8/13/1997	0.0053	0.8659	125	10/22/1997	-0.0079	-1.2851
26	6/5/1997	0.0015	0.2486	76	8/14/1997	-0.0069	-1.1168	126	10/23/1997	-0.0237	-3.8354
27	6/6/1997	-0.0082	-1.3355	77	8/15/1997	-0.0075	-1.219	127	10/24/1997	0.0095	1.5444
28	6/9/1997	0.0013	0.2122	78	8/18/1997	-0.0017	-0.2759	128	10/27/1997	-0.0038	-0.6115
29	6/10/1997	-0.0012	-0.1904	79	8/19/1997	-0.0112	-1.8082	129	10/28/1997	-0.0317	-5.0901
30	6/11/1997	-0.0026	-0.4286	80	8/20/1997	0.0065	1.0515	130	10/29/1997	0.0304	4.9204
31	6/12/1997	-0.0093	-1.5001	81	8/21/1997	0.0029	0.4718	131	10/30/1997	0.0013	0.2029
32	6/13/1997	0.0035	0.5667	82	8/22/1997	-0.0039	-0.6244	132	10/31/1997	0.0054	0.8823
33	6/16/1997	0.0019	0.3092	83	8/25/1997	0.0003	0.0484	133	11/3/1997	0.006	0.9641
34	6/17/1997	-0.0016	-0.2541	84	8/26/1997	-0.0041	-0.6693	134	11/4/1997	-0.0021	-0.3339
35	6/18/1997	-0.0059	-0.9591	85	8/27/1997	-0.005	-0.8099	135	11/5/1997	0.0001	0.0135
36	6/19/1997	-0.0011	-0.1765	86	8/28/1997	-0.0121	-1.9529	136	11/6/1997	-0.0077	-1.2506
37	6/20/1997	0.0029	0.4739	87	8/29/1997	-0.0133	-2.1465	137	11/7/1997	-0.0017	-0.2701
38	6/23/1997	0.0026	0.4228	88	9/1/1997	-0.0226	-3.6528	138	11/10/1997	-0.0052	-0.8392
39	6/24/1997	-0.002	-0.3311	89	9/2/1997	-0.0043	-0.6916	139	11/11/1997	-0.0019	-0.3007
40	6/25/1997	0.0033	0.5284	90	9/3/1997	0.0202	3.2689	140	11/12/1997	-0.0069	-1.1175
41	6/26/1997	0.0055	0.889	91	9/4/1997	0.0035	0.5687	141	11/13/1997	-0.001	-0.1586
42	6/27/1997	-0.0022	-0.3577	92	9/5/1997	0.0051	0.823	142	11/14/1997	0.0031	0.5036
43	6/30/1997	0.0022	0.3542	93	9/8/1997	0.0066	1.0613	143	11/17/1997	0.0066	1.0698
44	7/1/1997	-0.0017	-0.2754	94	9/9/1997	0.0153	2.4763	144	11/18/1997	0.0065	1.0497
45	7/2/1997	-0.0082	-1.3292	95	9/10/1997	-0.0043	-0.7013	145	11/19/1997	-0.0054	-0.874
46	7/3/1997	0.0011	0.1739	96	9/11/1997	-0.0058	-0.9369	146	11/20/1997	-0.0059	-0.9451
47	7/4/1997	0.0035	0.5704	97	9/12/1997	-0.0059	-0.9564	147	11/21/1997	0.0089	1.4474
48	7/7/1997	-0.0001	-0.0173	98	9/15/1997	0.006	0.9708	148	11/24/1997	-0.0016	-0.2513
49	7/8/1997	-0.0043	-0.702	99	9/16/1997	-0.0087	-1.4001	149	11/25/1997	-0.0139	-2.2486
50	7/9/1997	-0.0032	-0.5232	100	9/17/1997	-0.0048	-0.7728	150	11/26/1997	0.0062	1.004

Table 6: Estimation results - Fixed time effect and contagion - continued

$k$	Date	$\hat{\gamma}_{t^*+k}$	t-value	$k$	Date	$\hat{\gamma}_{t^*+k}$	t-value	$k$	Date	$\hat{\gamma}_{t^*+k}$	t-value
151	11/27/1997	-0.0066	-1.0667	201	2/5/1998	-0.0004	-0.0591	251	4/16/1998	-0.0077	-1.2456
152	11/28/1997	-0.0042	-0.6862	202	2/6/1998	0.0077	1.2398	252	4/17/1998	0.0004	0.0677
153	12/1/1997	0.0048	0.7806	203	2/9/1998	0.0121	1.9657	253	4/20/1998	-0.0003	-0.0559
154	12/2/1997	-0.0015	-0.2501	204	2/10/1998	0.0077	1.2463	254	4/21/1998	-0.0005	-0.088
155	12/3/1997	-0.007	-1.129	205	2/11/1998	-0.0009	-0.1464	255	4/22/1998	-0.0029	-0.4766
156	12/4/1997	0.0069	1.1178	206	2/12/1998	-0.0154	-2.4868	256	4/23/1998	-0.0026	-0.4206
157	12/5/1997	0.0048	0.7809	207	2/13/1998	-0.0215	-3.4883	257	4/24/1998	0.0013	0.2171
158	12/8/1997	-0.0105	-1.6984	208	2/16/1998	-0.0161	-2.6067	258	4/27/1998	-0.0054	-0.879
159	12/9/1997	-0.0063	-1.0174	209	2/17/1998	0.0088	1.4272	259	4/28/1998	0.0011	0.1734
160	12/10/1997	-0.0102	-1.6532	210	2/18/1998	0.0077	1.2431	260	4/29/1998	-0.0037	-0.6019
161	12/11/1997	-0.0223	-3.5981	211	2/19/1998	0.0055	0.8917	261	4/30/1998	0.0006	0.1002
162	12/12/1997	-0.0198	-3.2044	212	2/20/1998	-0.0037	-0.6014	262	5/1/1998	-0.0022	-0.3621
163	12/15/1997	-0.0115	-1.8549	213	2/23/1998	-0.0004	-0.0684	263	5/4/1998	-0.0096	-1.5617
164	12/16/1997	0.007	1.1305	214	2/24/1998	0.0042	0.6732	264	5/5/1998	-0.0034	-0.5503
165	12/17/1997	0.0082	1.3324	215	2/25/1998	-0.0003	-0.0433	265	5/6/1998	-0.0169	-2.7259
166	12/18/1997	0.013	2.1008	216	2/26/1998	0.0044	0.7163	266	5/7/1998	-0.0043	-0.6937
167	12/19/1997	-0.0127	-2.0511	217	2/27/1998	0.0113	1.8294	267	5/8/1998	0.0071	1.1532
168	12/22/1997	-0.0183	-2.9709	218	3/2/1998	0.0032	0.5181	268	5/11/1998	-0.0025	-0.4096
169	12/23/1997	-0.0109	-1.77	219	3/3/1998	0.0048	0.7696	269	5/12/1998	-0.0023	-0.3801
170	12/24/1997	-0.0012	-0.1892	220	3/4/1998	-0.0068	-1.0932	270	5/13/1998	-0.0232	-3.7449
171	12/25/1997	0	-0.0037	221	3/5/1998	-0.0184	-2.9729	271	5/14/1998	-0.0015	-0.2369
172	12/26/1997	0.014	2.2628	222	3/6/1998	-0.0033	-0.5281	272	5/15/1998	0.0079	1.273
173	12/29/1997	0.0037	0.6043	223	3/9/1998	-0.0027	-0.432	273	5/18/1998	-0.0143	-2.3164
174	12/30/1997	-0.0029	-0.4754	224	3/10/1998	-0.0002	-0.0284	274	5/19/1998	0.0014	0.228
175	12/31/1997	-0.0027	-0.4332	225	3/11/1998	0.0019	0.3157	275	5/20/1998	0.0105	1.7003
176	1/1/1998	0	-0.0037	226	3/12/1998	0.002	0.326	276	5/21/1998	0.0065	1.0587
177	1/2/1998	-0.0062	-1.004	227	3/13/1998	0.0153	2.4726	277	5/22/1998	0.0038	0.6126
178	1/5/1998	-0.0106	-1.7055	228	3/16/1998	-0.0025	-0.4072	278	5/25/1998	-0.0026	-0.4153
179	1/6/1998	-0.0094	-1.5172	229	3/17/1998	0.0041	0.6641	279	5/26/1998	0.0015	0.2465
180	1/7/1998	-0.0161	-2.6053	230	3/18/1998	-0.0051	-0.8195	280	5/27/1998	-0.0149	-2.4072
181	1/8/1998	-0.0443	-7.1541	231	3/19/1998	0.0097	1.5668	281	5/28/1998	-0.012	-1.94
182	1/9/1998	-0.0061	-0.9896	232	3/20/1998	0.0063	1.0132	282	5/29/1998	0.0073	1.185
183	1/12/1998	-0.0148	-2.3858	233	3/23/1998	0.0051	0.8235				
184	1/13/1998	0.0271	4.3879	234	3/24/1998	0.0014	0.2234				
185	1/14/1998	0.0319	5.1294	235	3/25/1998	0.0009	0.1493				
186	1/15/1998	-0.0184	-2.9825	236	3/26/1998	0.0016	0.2539				
187	1/16/1998	0.0123	1.9929	237	3/27/1998	-0.0001	-0.0184				
188	1/19/1998	0.0169	2.7277	238	3/30/1998	-0.0091	-1.468				
189	1/20/1998	-0.0047	-0.7691	239	3/31/1998	-0.006	-0.9698				
190	1/21/1998	-0.0058	-0.9374	240	4/1/1998	-0.0088	-1.4246				
191	1/22/1998	-0.0282	-4.5619	241	4/2/1998	-0.0108	-1.7504				
192	1/23/1998	-0.0054	-0.8689	242	4/3/1998	-0.0095	-1.5457				
193	1/26/1998	0.0199	3.2154	243	4/6/1998	0.0014	0.2238				
194	1/27/1998	0.018	2.9211	244	4/7/1998	0.0042	0.68				
195	1/28/1998	0.0062	1.0114	245	4/8/1998	0.0091	1.4792				
196	1/29/1998	0.0013	0.2103	246	4/9/1998	0.01	1.6174				
197	1/30/1998	0.0144	2.324	247	4/10/1998	0.0011	0.1703				
198	2/2/1998	0.044	7.0849	248	4/13/1998	0.0107	1.7279				
199	2/3/1998	-0.0125	-2.0161	249	4/14/1998	-0.0063	-1.0272				
200	2/4/1998	-0.0098	-1.5871	250	4/15/1998	-0.0044	-0.713				

1.61. China is also significantly impacted by the world returns index. Interestingly, global vulnerabilities are not as significant for countries with less developed equity markets such as Indonesia, India, Thailand and the Philippines. Regional vulnerabilities have a significant and positive impact on all countries of the sample, probably reflecting trade, financial and economic linkages arising geographically. The parameter estimates on the MSCI Asia index range between 0.27 for Japan, to 1.33 for Korea. It is likely that regional linkages are relatively more important for countries with less developed financial markets due to trade linkages compared to overall world linkages.

## **5.2 Contagion**

The time series of the fixed time effects is presented in figure 1. The first panel of the figure presents the coefficient estimates, and the second panel presents the t-value associated with each estimate along with the corresponding 99 percent critical values. Inspection of this figure shows evidence of joint contagion across all eleven countries for equity returns in four clear episodes as measured by their significance at the 99 percent level. When contagion is evident, the parameter estimates of the fixed time effects are generally large in absolute terms, and tend to cluster. The episodes of contagion correspond to the periods: (i) September 1 to September 3, 1997, (ii) October 23 to October 29, 1997, (iii) December 11, 12 and 22, 1997 and (iv) January 7 to February 16, 1998 along with several dates in March and May of 1998 which are not so clustered together.

Altogether there are 23 dates on which there is contagion, which represents approximately eight percent of all observations in the fixed time effects window. On the remaining 92 percent of days, equity market prices are determined by global and regional vulnerabilities. It is also clear that contagion is not just a negative phenomenon marked by simultaneously falling equity markets. There are about as many instances of positive contagion

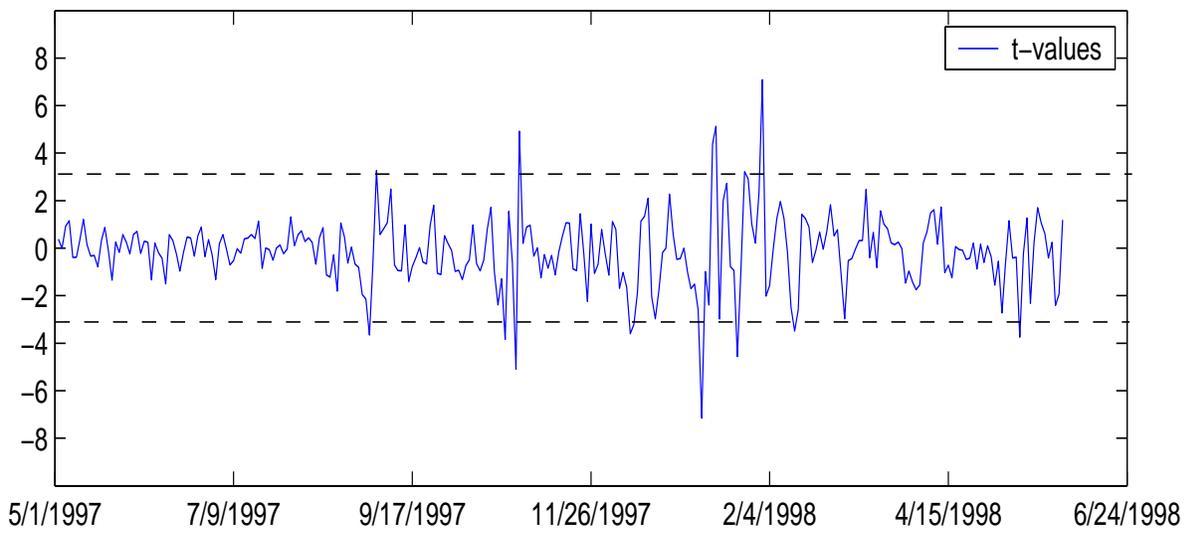
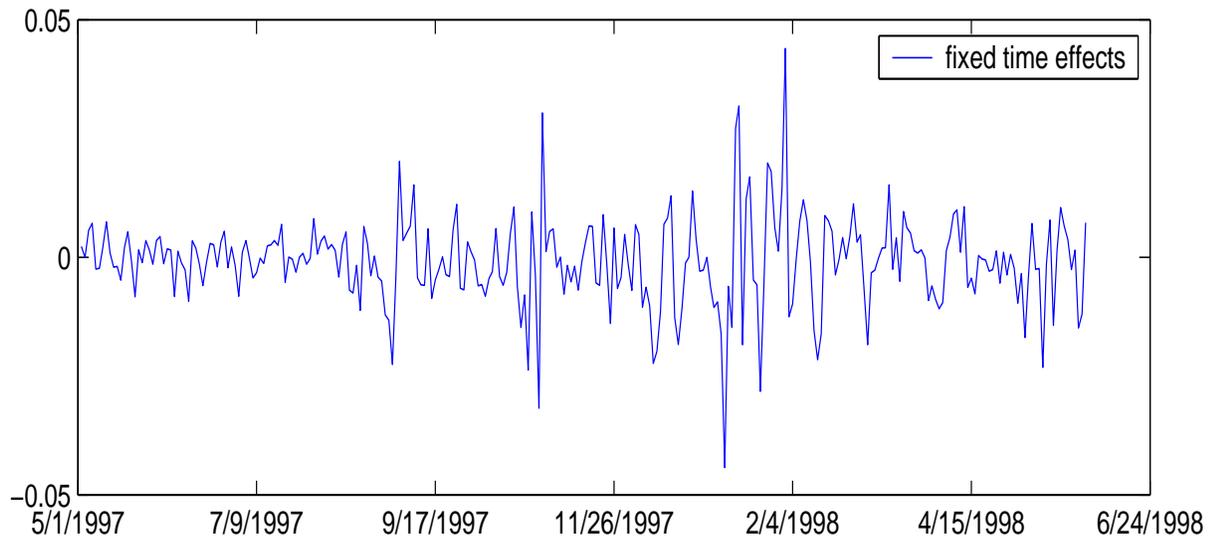


Figure 1: *Panel (a): Estimates of the Fixed Time Effects in equation (1), Panel (b): corresponding t-values and 99 percent critical values*

as negative contagion. Some of the instances of positive contagion are also quite large in terms of absolute value. This is an important finding with implications for investor diversification and optimal portfolio allocation, as portfolio diversification decisions are made based on measures of the strength and direction of the common movement of asset prices.

**(i) September 1 to September 3, 1997** The key item of news to hit financial markets in the first period of contagion corresponding to September 1 to 3 in 1997 was the announcement on September 1 that the Malaysian Government had imposed restrictions on forward sales of the ringgit and banned short-selling in equity markets (Appendix A, Kaminsky and Schmukler, 1999b, Athukorala, 2001). The fixed time effect on September 3 is positive (0.02), compared to the negative value of -0.02 on September 1. The similarity of the absolute magnitudes of these contagious events also suggests a market correction.

**(ii) October 23 to 29, 1997** The second period of contagion overlaps the period of the Hong Kong speculative attack and equity market crash of October 1997 and the following US equity market crash where the US Dow Jones lost over 7 percent of its value in one day (see Appendix A, BBC 1998, Roubini 1998, and the Washington Post, 1998). The Hong Kong speculative attack began on December 20th and lasted for just over a week, with most of the impact felt on the 20th to the 23rd. This event is considered to be one of the most important of the Asian crisis. The fixed effects are not significant for every day of the period of the attack, but are significant on October 23, 28 and 29, as is clearly demonstrated in Figure 1. The parameters are negative on October 23 and 28, but there is evidence of positive contagion on October 29, potentially indicating the end of the speculative attack and a reversal in market sentiment. The negative contagion effect on October 28 reflects the response (given the time difference between New York and Asia) of the Asian markets to the US crash. Several countries were also downgraded or put on review

for downgrade by Moody's and Standard and Poors during the turbulent Hong Kong crash period.

**(iii) December 11, 12 and 22, 1997** The third period of contagion which occurs on December 11, 12 and 22, 1997 corresponds to issues affecting Korea at this time. An internal IMF document leaked on December 10 stated that two banks would close, foreign exchange reserves had rapidly depleted, and short term debt was almost double that suggested in government statements (Appendix A, Roubini, 1998). On December 11 and 12, trading of the Korean Won was halted in reaction to the previous days news, and equity markets fell markedly during this time. On December 22, the sovereign debt ratings of Indonesia, Malaysia and Korea were downgraded by Moody's investor service. Over the course of 1997 this represented a downgrade from an investment grade rating to junk status for Korea.

**(iv) January to May, 1998** The fourth period of contagion in early 1998 is the longest in duration and the most extreme in terms of magnitude of the parameter estimates. The chronology shows that there was substantial financial, economic and political turmoil in many countries throughout the region over this time, and there are clear instances of both negative and positive contagion effects reflecting the intensity of the uncertainty of this period. In the month of January there are four instances of negative contagion (January 7, 8, 15 and 22), and five instances of positive contagion (January 13, 14, 19, 26 and 27). Apart from one more instance of positive contagion on February 2, contagion is negative on February 13 and 16, March 5 and 6, and May 13, 1998.

Negative contagion on January 8 coincides with turmoil in Indonesian financial markets; reports hit the market that the IMF was unhappy with Indonesia's commitment to reform. Equity markets fell by up to 19 percent over the day, and the Rupiah per USD ex-

change rate broke 10,000 which was 70 percent lower than the rate of July 1997 (Roubini, 1998). Indonesia was in the midst of its crisis in January, with political uncertainty surrounding the forthcoming presidential elections. Further, Korea, who had successfully negotiated with foreign banks to roll over their short term debt in the previous December, was negotiating the rollover of the US Dollar 20 billion in short term debt due later in the month (Roubini, 1998), although Korea was also the beneficiary of US Dollar 2 billion from the IMF earlier in the month. Thailand and Indonesia were downgraded by rating agencies, and several other countries were due to have their ratings announced in the subsequent days. The value of the fixed time effect on this date is  $-0.044$  and is significant with a t-value of  $-7.15$  indicating quite extreme negative contagion amongst most of the countries in the sample.

The significant fixed time effects of January 13, 14 and 22, 1998, appear to be driven by market sentiment. The fixed time effect is positive on January 14 with a value of 0.032. Regional equity markets rebounded because of positive sentiment surrounding the IMF program being developed for Indonesia (Roubini, 1998), and Hong Kong bank rates fell (Kaminsky and Schmukler, 1999a), despite the collapse of the Hong Kong based Peregrine Investments which collapsed the previous day. The negative fixed time effect on January 22 reflects uncertainty in Indonesia and a further plummet of the Rupiah which impacted on regional equity markets (Roubini, 1998 and Kaminsky and Schmukler, 1999a). The announcement of the creation of the Indonesian Bank Restructuring Agency on January 22 did little to instill confidence in the markets.

In the final period of positive contagion between January 26 and February 2, 1998, events in Korea and Indonesia were largely in the headlines. Korea successfully negotiated the roll over of a series of short term debt contracts into longer term instruments, which in turn strengthened the Korean banking sector (Appendix A, BBC, 1998 and Roubini, 1998).

This was accompanied by the closure of many illiquid merchant banks, while the banking sector in Indonesia was also under reform (Roubini, 1998 and Kaminsky and Schmukler, 1999a). The final dates on which contagion is extreme are February 13 and 16, March 3, May 6 and 13. Contagion during this period of the crisis seems likely to be linked to civil and political unrest in Indonesia, as well as the intense debate about the suitability of a currency board for Indonesia and the IMF's subsequent adverse reaction.

**The impact of Hong Kong, Indonesia and Korea** In matching contagion with anecdotal news events, no one type of event detailed in the chronology appeared to be a cause of contagion. The turmoil of early 1998 featured in the timing of contagion, but there does not appear to be a systematic event causing contagion. However, Hong Kong, Indonesia and Korea (three of the key crisis countries) seem to be prominently in the headlines corresponding to days on which contagion was important. The hypothesis that the Hong Kong speculative attack is an important event in the crisis is supported by the results of this paper with the detection of contagion during the October 1997 period. To examine the importance of Hong Kong in explaining contagion, Hong Kong returns are included in the vector of exogenous variables and the model is reestimated. The resulting parameter estimates of the fixed time effects and the corresponding t-values are presented in figure 2. Controlling for Hong Kong eliminates most of the periods of contagion, with the exception of some of the dates in early January 1998. This result confirms the importance of the Hong Kong attack in contributing to asset market volatility during the period. The inclusion of Hong Kong as an explanatory variable in the model increases the value of  $R^2$  considerably from 31.46% to 37.16%. The F-statistic is lower but still significant. Performing similar experiments with the Korean, Indonesian and Thai returns does not markedly eliminate the period of contagion.

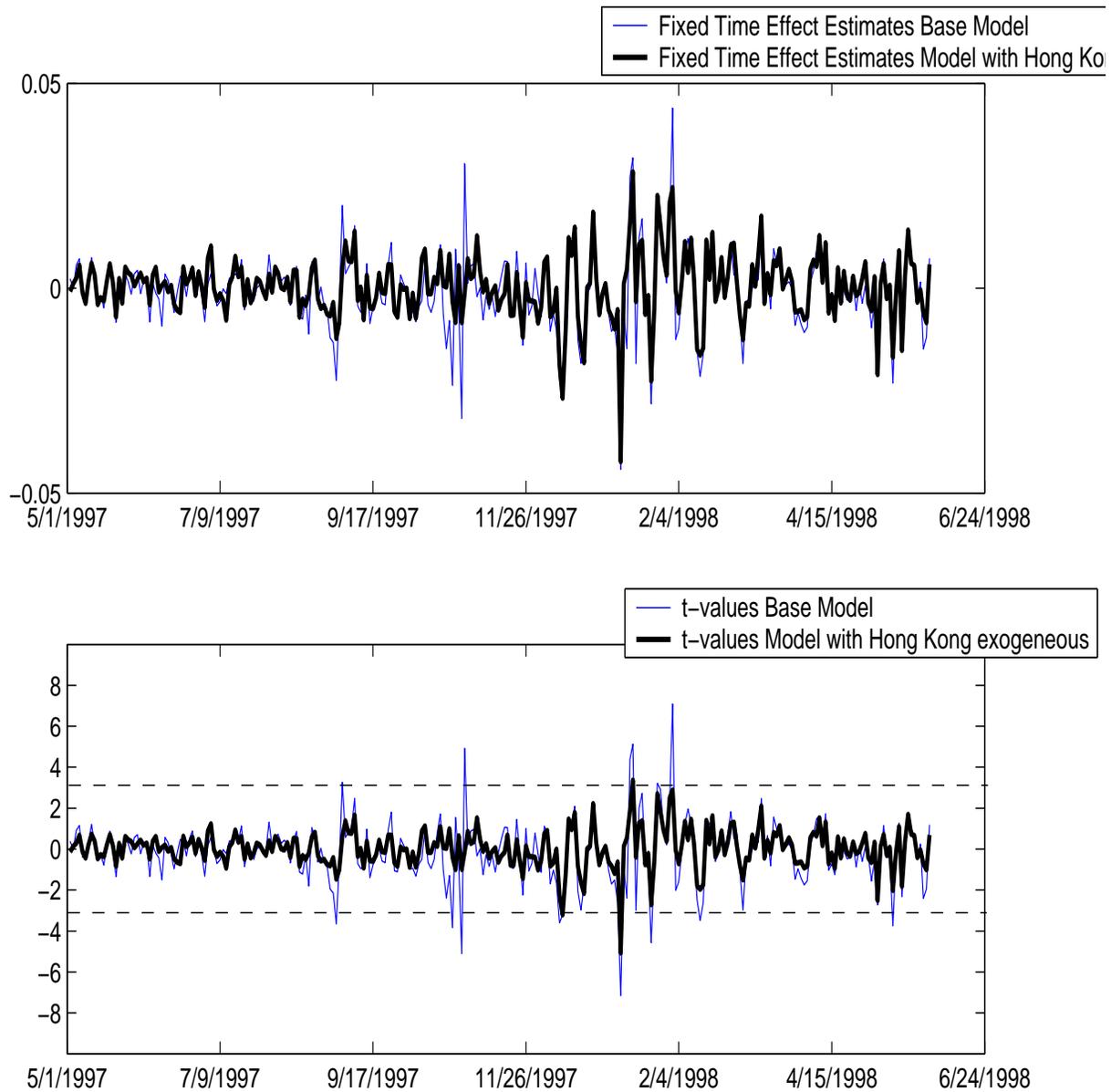


Figure 2: Panel (a): Comparison of the Fixed Time Effects in equation (1) with and without Hong Kong as an additional variable, Panel (b): corresponding t-values and 99 percent critical values

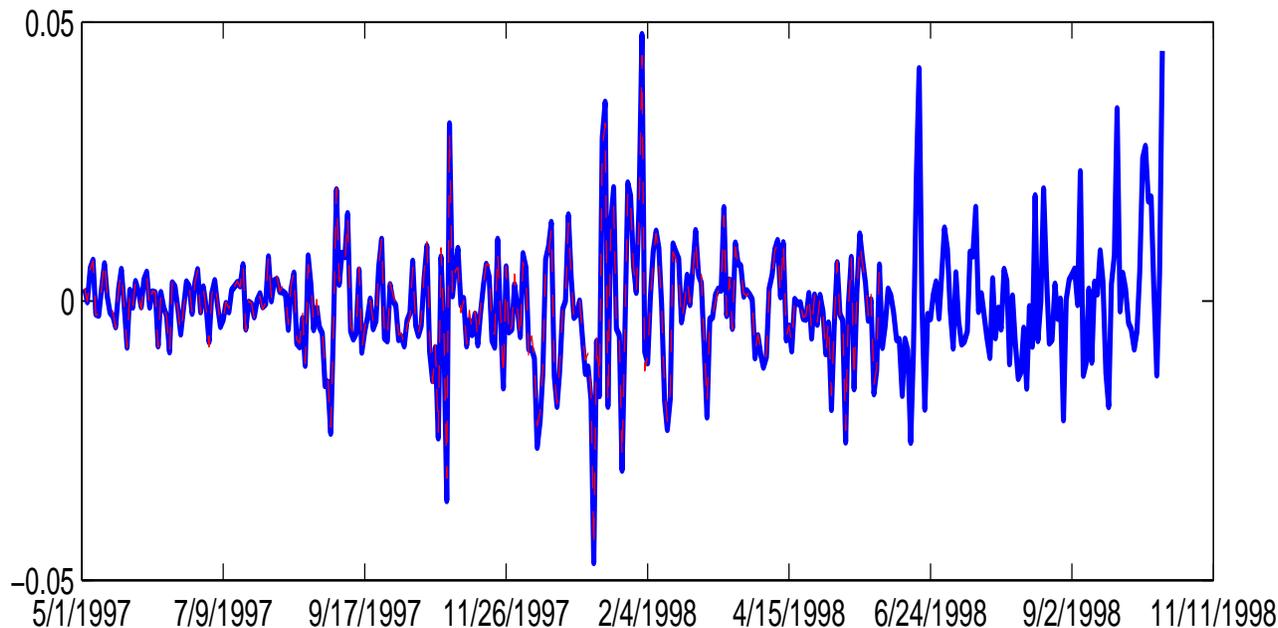


Figure 3: *Robustness analysis: comparison of fixed time effect estimates of base period with an extended period*

### 5.3 Robustness Analysis

The estimates of contagion depend on the exogenous variables in the model and the period over which the fixed time effects are defined. In addition to specifically accounting for Hong Kong, Indonesia and Korea as in the previous section, five experiments are undertaken to evaluate the robustness of the model to alternative specifications. The first two experiments evaluate the robustness of the definition of the fixed time effects, the third and fourth experiments evaluate the importance of the variables measuring vulnerabilities, while the final experiment estimates a model without controlling for vulnerabilities. Figures 3 and 4 present the parameter estimates of the fixed time effects for each of the experiments.

The panel model was also estimated with homogeneous slopes for the common factors, as well as a dynamic specification with lagged dependent and independent variables in

first differences. These alternative specifications did not change the incidence of contagion. Therefore, the results are not reported. Finally, the model was also estimated using Newey-West heteroscedastic and serial correlation consistent standard errors. This adjustment reduced the t-values of the fixed time effects, but only notably for periods of joint positive contagion. The occurrences of simultaneous negative contagion are still significant with this correction.

In the first and second experiments, restricted versions of the model presented in equation (1) are estimated by redefining the window of the fixed time effects. In the first experiment the period that encompasses the crisis is extended by 100 trading days, so that the fixed time effects are defined over May 1, 1997 to October 16, 1998, for a total of 382 trading days. Similarly, in the second experiment, the time-window for the fixed time effects is moved ‘to the right’ by specifying the value of  $t_0$  to begin 50 trading days later. This also means that the fixed time effects end 50 trading days later. The window is thus redefined from July 9, 1997 to August 7, 1998. In both cases, the redefinition of the fixed time effect do not significantly change the fixed time effects estimates compared to the original window. In experiment one, some additional dates where contagion is significant are detected, but this is probably due to the Russian bond default of August 1998 and the preceding financial market pressures. This is shown graphically in the first panel of figure 3. Because the sample does not include countries important to this crisis such as Russia, no analysis is provided of these additional contagious episodes. In both cases, the parameters measuring vulnerabilities  $\hat{\beta}_{i1}$  and  $\hat{\beta}_{i2}$ , change slightly, while the  $R^2$  and the  $F$ -statistic increase. Since neither of the modifications to the fixed time effects window dramatically change the characteristics of the fixed time effects series, it is reasonable to conclude that the estimates are rather robust to such variations.

Experiments three to five examine the relative importance of the variables measuring

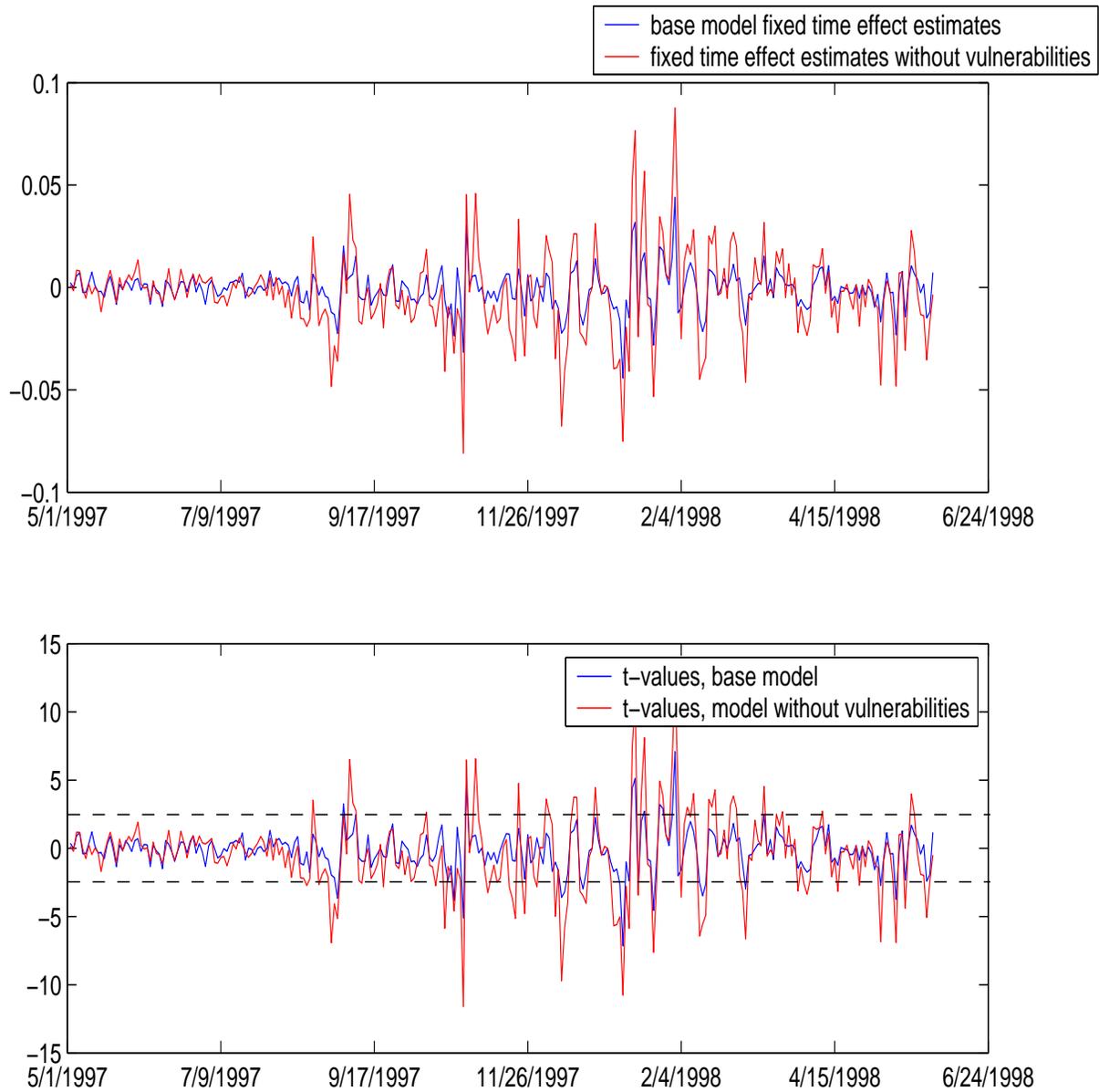


Figure 4: *Robustness analysis: Impact of vulnerabilities. Panel (a): Comparison of estimates of the Fixed time effects in equation (1) with and without controlling for vulnerabilities, Panel (b): corresponding t-values and 99 percent critical values*

vulnerability in equation (1). In the third experiment, the condition  $\beta_{i1} = 0 \forall i$  is imposed and vulnerability is defined only with respect to the world factor. The parameter estimates of the fixed time effects,  $\hat{\gamma}_{t^*}$  do not considerably change, but the values of  $\hat{\beta}_{i2}$  markedly increase with many estimates more than quadrupling. The  $R^2$  value decreases to 14.21%, and the corresponding F-statistic increases to  $F = 109.7231$ . Similar results hold in experiment four, where only regional vulnerabilities are considered by excluding the MSCI World Index. That is,  $\beta_{i2} = 0 \forall i$ . Again, the characteristics and especially the extremes of the fixed time effects do not change. However, the estimates of  $\hat{\beta}_{i1}$  slightly increase for all markets. The  $R^2$  value decreases slightly and the F-statistic increases considerably. In the final experiment, both vulnerability factors are excluded, and only the fixed time effects are estimated ( $\beta_{ij} = 0 \forall i, j$ ). Just estimating the fixed time effects yields more volatile parameter estimates and also more extremes. The  $R^2$  drops to 11.93% and the F-statistic is 247.11. Figure 4 shows the difference of the fixed time effects for the base model presented in equation (1) and the restricted model with  $\beta_{ij} = 0 \forall i, j$ . The results of the robustness analysis support the idea that vulnerabilities account for a significant amount of comovement and affect the incidence of contagion.

## 6 Concluding Remarks

This paper presented a multivariate test for contagion using panel data analysis techniques for the Asian financial crisis of 1997-1998. The methodology controlled for common vulnerabilities which arise through countries susceptibility to shocks from nearby countries, as well as from global financial markets through economic and financial linkages. Contagion was defined as unexpected and significant joint positive or negative movements in the asset returns of the relevant countries, and was modelled through the significance of fixed time effects.

This approach of analyzing contagion has several advantages. First, the large panel data set enables a long time varying time series to be extracted to measure contagion. This means that the sample selection bias problem discussed in Pesaran and Pick (2004) is overcome, and the level of contagion can be determined endogenously as it is possible to specify a fixed time effect window which encompasses the entire crisis period. The second advantage is that the methodology is able to distinguish between positive and negative contagion. This has important implications for investors trying to diversify their portfolios internationally. A final advantage is that the source country from which contagion emanated can be detected but does not need to be identified.

The results showed that there were four periods where contagion was significant. These were (i) September 1 to September 3, 1997, (ii) October 23 to October 29, 1997, (iii) December 11, 12 and 22, 1997 and (iv) January 7 to February 16, 1998 along with several dates in March and May of 1998. This is equivalent to about eight percent of observations over the crisis period. The remaining dates over the period in which the fixed time effects were defined did not display evidence of contagion; asset market volatility on these dates can be explained by vulnerabilities. Analyses of the events of the dates on which the fixed time effects are significant anecdotally suggest that much contagion can be explained by shocks in the Hong Kong market, particularly the Hong Kong speculative attack of October 1997. Contagion also seemed to surround events in Indonesia and Korea. Comparing the dates on which contagion occurred with a chronology of the crisis indicated that there did not seem to be a 'type' of event such as a IMF policy, political or rating event which systematically caused contagion. Finally, there were almost as many positive instances of contagion as negative ones.

## 7 References

- Athukorala, P-C., 2001, *Crisis and Recovery in Malaysia: The Role of Capital Controls*, Edward Elgar Publishing Limited, UK.
- Bae, K.H., Karolyi, G.A. and Stulz, R.M., 2003, "A New Approach to Measuring Financial Contagion", *Review of Financial Studies*, 16, 717-763.
- Baig, T. and Goldfajn, I., 1999, "Financial Market Contagion in the Asian Crisis", *IMF Staff Papers*, 46(1), 167-195.
- Bank for International Settlements, 1998, "Chronology of the Crisis", *Bank for International Settlements 68th Annual Report*. Bank for International Settlements, Basle.
- Barberis, N., Shleifer, A. and Wurgler, J., 2002, Comovement, NBER Working Paper No. 8884
- Baur, D. and Schulze, N., 2005, "Coexceedances in Financial Markets - A Quantile Regression Analysis of Contagion", *Emerging Markets Review*, 6, 21-43.
- Bekaert, G., Harvey, C.R. and Ng, A., 2005, "Market Integration and Contagion", *Journal of Business*, 78, 39-70.
- BBC, 1998, "Business: The Economy Meltdown in Asia - Part 4: Chronology of a Crisis," [http://news.bbc.co.uk/1/hi/business/the\\_economy/122546.stm](http://news.bbc.co.uk/1/hi/business/the_economy/122546.stm).
- Calvo, S. and Mendoza, E. 2000, "Rational Contagion and the Globalization of Securities Markets ", *Journal of International Economics*, 51, 79-113.
- Calvo, S. and Reinhart, C., 1996, "Capital Flows to Latin America: Is there Evidence of Contagion Effects", *World Bank Policy Research Working Paper*, No. 1619.

- Cameron, L., 1999, "Survey of Recent Developments" *Bulletin of Indonesian Economic Studies*, 35(1), 3-41.
- Chopra, A., Kang, K., Karasulu, M., Liang, H., Ma, H. and Richards, A., 2001, "From Crisis to Recovery in Korea: Strategy, Achievements and Lessons", *IMF Working Paper* WP/01/154.
- Corsetti, G., Pericoli, M. and Sbracia, M., 2002, "Some Contagion, Some Interdependence: More Pitfalls in Tests of Financial Contagion", *CEPR Discussion Paper*, No. 3310.
- Corsetti, G., Pericoli, M. and Sbracia, M., 2001, Correlation Analysis of Financial Contagion: What One Should Know Before Running a Test, *Economic Growth Centre Discussion Paper* No. 822, Yale University.
- Debelle, E. and Ellis, L., 2005, The Response of Financial Markets in Australia and New Zealand to News about the Asian Crisis, in Dungey, M. and Tambakis, D. (eds), *Identifying International Financial Contagion: Progress and Challenges*, Oxford University Press, New York.
- Dungey, M., Fry, R.A., Gonzalez-Hermosillo B. and Martin, V.L., 2005a, "Empirical Modelling of Contagion: A Review of Methodologies", *Quantitative Finance*, 75(1), 9-24.
- Dungey, M., Fry, R.A., Gonzalez-Hermosillo B. and Martin, V.L., 2005b, "A Monte Carlo Analysis of Alternative Tests of Contagion", mimeo Australian National University.
- Dungey, M., Fry, R.A. and Martin, V.L., 2003, "Equity Transmission Mechanisms from Asia to Australia: Interdependence or Contagion?", *Australian Journal of Management*, 28(2), 157-182.
- Dungey, M. and Martin, V.L., 2004, "A Multifactor Model of Exchange Rates with Unanticipated Shocks: Measuring Contagion in the East Asian Currency Crisis", *Journal*

*of Emerging Markets Finance*, 3(3), 305-330.

Dungey, M. and Zhumabekova, D., 2001, "Testing for Contagion Using Correlations: Some Words of Caution", *Pacific Basin Working Paper*, No. 01-09, Federal Reserve Bank of San Francisco.

Eichengreen, B., Rose, A.K. and Wyplosz, C., 1996, "Contagious Currency Crises: First Tests", *Scandinavian Journal of Economics*, 98,463-484.

Eichengreen, B., Rose, A.K. and Wyplosz, C., 1995, "Exchange Market Mayhem: The Antecedents and Aftermath of Speculative Attacks", *Economic Policy: A European Forum*, 21, 249-296.

Favero, C.A. and Giavazzi, F., 2002, "Is the international Propagation of Financial Shocks Non-Linear? Evidence from the ERM", *Journal of International Economics*, 57, 231-246.

Forbes, K. and Rigobon, R., 2002, "No Contagion, Only Interdependence: Measuring Stock Market Co-movements", *Journal of Finance*, 57(5), 2223-2261.

Fratzscher, M., 1999, "What Causes Currency Crises: Sunspots, Contagion or Fundamentals?" EUI Working Paper Eco No. 99/ 39.

Fratzscher, M., 2002, "On Currency Crises and Contagion", *ECB Working Paper*, No. 139.

Greene, W.H., 2002, *Econometric Analysis*, 5th edition, Prentice Hall.

International Monetary Fund, 2000, "Recovery from the Asian Crisis and the Role of the IMF", *Issues Briefs*, 00/05.

International Monetary Fund, 1999, "The IMF's Response to the Asian Crisis", *A Fact Sheet*, January 1999.

- International Monetary Fund, 1998, "Seminar on Capital Account Liberalization", transcript of a press conference, IMF Meeting Hall, Washington DC, March 10, 1998.
- Jomo, K.S. (1998), "Malaysian Debacle: Whose Fault?", *Cambridge Journal of Economics*, 22, 707-722.
- Kaminsky, G.L. and Schmukler, S.L., 1999a, "What Triggers Market Jitters? A Chronicle of the Asian Crisis", mimeo, George Washington University.
- Kaminsky, G.L. and Schmukler, S.L., 1999b, "What Triggers Market Jitters? A Chronicle of the Asian Crisis", *Journal of International Money and Finance*, 18, 537-560.
- Karolyi, G.A. and Stulz, R.M., 1996, "Why do Markets Move Together? An Investigation of US-Japan Stock Return Comovements", *Journal of Finance*, 51(3), 951-986.
- Kodres, L.E. and Pritsker, M., 2002, "A Rational Expectations Model of Financial Contagion", *Journal of Finance*, 57(2), 768-799.
- Lindgren, C-J, Baliño, T.J.T. Enoch, C., Gulde, A-M., Quintyn, M. and Teo, L., 1999, "Financial Sector Crisis and Restructuring: Lessons from Asia", *Occasional Paper No. 188*, IMF.
- Longin, F. and Solnik, B., 1995, "Is the Correlation in International Equity Returns Constant: 1960-1990?", *Journal of International Money and Finance*, 14(1), 3-26.
- Masson, P.R., 1999, "Contagion: Monsoonal Effects, Spillovers, and Jumps Between Multiple Equilibria", in Agénor, P., Miller, M. and Vines, D. (eds), *The Asian Crises: Causes, Contagion and Consequences*, Cambridge: Cambridge University Press.
- Ministry of Finance, 1999, *Thailand's Economic Reform: Progress Report January 1999*, Fiscal Policy Office, Ministry of Finance, Kingdom of Thailand.

- Moody's Investors Service, 2002, *Sovereign Rating History: Special Comment*, Moody's Investors Service, New York, USA.
- Mody, A. and Taylor, M., 2003, "Common Vulnerabilities", *CEPR Research Discussion Paper*, DP3759.
- Pesaran, H. and Pick, A., 2004, "Econometric Issues in the Analysis of Contagion", *CE-SIFO Working Paper*, No. 1176.
- Pericoli, M. and Sbracia, M., 2003, "A Primer on Financial Contagion", *Journal of Economic Surveys*, 17, 571-608.
- Rigobon, R., 2003, "On the Measurement of the International Propagation of Shocks: Is the Transmission Stable?", *Journal of International Economics*, 61, 261-283.
- Roubini, N., 1998, home page Stern School of Business, New York University  
<http://pages.stern.nyu.edu/~nroubini/asia/AsiaChronology1.html>  
<http://pages.stern.nyu.edu/~nroubini/asia/AsiaChronology1998.html>  
<http://pages.stern.nyu.edu/~nroubini/asia/AsiaChronology1998Q2.html>
- Siamwalla, A., 2001, "Anatomy of the Crisis", in Warr, P. (ed), in *Thailand Beyond the Crisis*, Routledge, London.
- Soesastro, H. and Bastri, C., 1998, "Survey of Recent Developments", *Bulletin of Indonesian Economic Studies*, 34(1), 3-54.
- Standard and Poor's (2004), *Sovereign Ratings History Since 1975*, Standard and Poor's, New York, USA, September 2, 2004.
- Van Rijckeghem, C. and Weder, B., 2000, "Spillovers through Banking Centres: A Panel Data Analysis", *IMF Working Paper* WP/00/88.

Washington Post, 1998, 'Asia's Financial Crisis 1997-1999 "

<http://www.washingtonpost.com/wp-srv/business/longterm/asiaecon/timeline.htm>

Warr, P., 2001, "Boom Bust and Beyond", in Warr, P. (ed), *Thailand Beyond the Crisis*,  
Routledge, London.

## **A Appendix A: Chronology of the Crisis.**

This chronology documents events that occurred during the Asian crisis period. These events are sorted into four categories. These are key crisis events, IMF policy events, political events and country rating events. Five tables are presented which contain the relevant details. Table 7 documents the key crisis (economic) events, table 8 documents key IMF policy related events, table 9 documents key political events and tables 10 and 11 document sovereign ratings changes for the relevant sample countries in 1997 and 1998 respectively.

Table 7: Chronology of the Asian crisis - key crisis events.

Date	Country	Event
1997		
Jun	27 Thailand	Suspension of 16 finance companies.
Jul	2 Thailand	Baht devaluation.
	11 Indonesia	Trading band around the rupiah widened.
	The Philippines	Trading band around the ringgit widened.
	14 Malaysia	Defense of the ringgit abandoned.
Aug	5 Thailand	42 finance companies suspended.
	14 Indonesia	Float of the rupiah.
Sep	1 Malaysia	First capital controls instituted.
	16 Indonesia	Government policy to address crisis announced.
Oct	17 Taiwan	Devaluation of New Taiwan dollar.
	Thailand	Financial sector restructuring agency established.
	Malaysia	1998 budget announced. Widely interpreted as inadequate.
	20-23 Hong Kong	Speculative attack.
	27 US	NYSE briefly halts trading.
Nov	1 Indonesia	Closure of 16 banks announced.
	17-19 Korea	Widening of trading band around won. Won trading suspended.
	17 Japan	Hokkaido Takushoku Bank collapses.
	24 Japan	Yamaichi securities collapses.
Dec	5 Malaysia	Policy package to deal with the crisis announced.
	8 Thailand	Only 2 of the suspended finance companies to resume trading.
	9 Korea	Govt. takes over two major banks to prevent their collapse.
	11-12 Korea	Trading of won halted.
	24 Korea	Moves to avoid debt moratorium in Korea. World Bank and Asian Development Bank to disburse USD5bn.
	29 Korea	Financial Supervision Commission Established.
1998		
Jan	6 Indonesia	Budget.
	7 Malaysia	National Economic Action Council established to deal with crisis.
	12 Hong Kong	Peregrine Investments Holdings Ltd collapses.
	22 Indonesia	Indonesian Bank Restructuring Agency (IBRA) created and other reforms.
	23 Korea	Foreign banks agree to roll over Korea's short term debt.
	30 Korea	10 merchant banks closed.
Mar	24 Malaysia	Announcement that three banks may need recapitalization.
	27 Japan	\$133 bn fiscal stimulus package announced.

Table 8: Chronology of the Asian crisis - IMF policy events.

Date	Country	Event
1997		
Jul	2 Thailand	Call for IMF assistance.
	18 The Philippines	IMF extends and increases the current extended fund facility credit.
Aug	11 Thailand	IMF rescue package announced.
	14 Thailand	Letter of intent.
	20 Thailand	US4bn stand by credit approved, US1.6bn disbursed.
Oct	8 Indonesia	Announcement of intention to seek support from the IMF.
	31 Indonesia	Indonesia letter of intent.
Nov	5 Indonesia	US10bn stand-by credit approved, US3bn disbursed.
	21 Korea	Request for IMF assistance.
	25 Thailand	Letter of intent.
Dec	4 Korea	US21bn stand-by credit approved, US5.6bn disbursed.
	8 Thailand	Review of the stand-by arrangement completed, US810mn disbursed.
	10 Korea	Internal IMF document leaked stating two banks to close, FX reserves low, short term debt almost double government statements.
	18 Korea	US3.5bn disbursed.
	30 Korea	Part of the amount scheduled for February and May 1998 brought forward and US2bn disbursed.
1998		
Jan	7 Korea	Letter of intent.
	8 Korea	US2bn disbursed.
	8 Indonesia	Report of IMF's unhappiness with Indonesia's commitment to reform.
	15 Indonesia	Memorandum of Economic and Financial Policies.
	17 Malaysia	IMF announces that Malaysia does not require assistance.
Feb	7 Korea	Letter of intent.
	13 Indonesia	IMF opposes Indonesia's suggestion of adopting a currency board.
	17 Korea	Quarterly review of the stand-by arrangement completed, US2bn disbursed.
	24 Thailand	Letter of intent.
Mar	4 Thailand	Second review of the stand-by arrangement completed, US270mn disbursed.
Apr	10 Indonesia	Supplementary Memorandum of Economic and Financial policies.
May	4 Indonesia	First review of the stand-by arrangement completed and US1bn disbursed.
	26 Thailand	Letter of intent.
	29 Korea	Second quarterly review of the stand-by completed, US2bn disbursed.
Jun	10 Thailand	Third review of the stand-by arrangement, US125mn disbursed.
	24 Indonesia	Supplementary Memorandum of Economic and Financial policies.
Jul	15 Indonesia	Second review of the stand-by arrangement completed, US1bn disbursed. Increase in IMF financing under the stand-by credit by US1.3bn announced.
	24 Korea	Letter of intent.
	29 Indonesia	Letter of intent and Memorandum of Economic and Financial policies.

Table 9: Chronology of the Asian crisis - key political events.

Date	Country	Event	
1997			
Sep	1	Malaysia	Mahathir sacks finance minister Ibrahim.
Nov	4	Thailand	Prime Minister Chavalit resigns.
	5	Indonesia	Decision to reverse liquidation of Bank Andromeda, belonging to Suharto's son.
	9	Thailand	Chuan Leekpai new Prime Minister.
	18	Korea	Finance minister resigns.
Dec	6	Indonesia	Rumors of Suharto's ill health.
	18	Korea	Kim Dae Jung elected new president.
1998			
Feb	9-12	Indonesia	Govt considers adopting currency board. Six students killed in riots.
	17	Indonesia	Suharto fires Central Bank governor.
Mar	10	Indonesia	Suharto re-elected.
May	21	Indonesia	Suharto resigns. Habibe successor.

Table 10: Chronology of the Asian crisis - key rating events 1997.

Date	Country	Event
1997		
Jun	24 Thailand	Moody's rating confirmed, with negative outlook.
Aug	1 Thailand	Standard and Poors outlook changed from stable to negative.
	6 Korea	Standard and Poors outlook changed from stable to negative.
	18 Malaysia	Standard and Poors outlook changed from positive to stable.
Sep	3 Thailand	Standard and Poors rating downgraded, negative outlook.
	9 Thailand	Moody's rating on review for downgrade.
	25 Malaysia	Standard and Poors outlook changed from stable to negative.
	25 The Philippines	Standard and Poors outlook changed from positive to stable.
Oct	1 Thailand	Moody's rating downgraded with stable outlook.
	6 India	Standard and Poors outlook changed from positive to stable.
	10 Indonesia	Standard and Poors rating downgraded, stable outlook.
	22 Thailand	Moody's rating on review for downgrade.
	24 Korea	Standard and Poors rating downgraded, negative outlook.
	24 Thailand	Standard and Poors rating downgraded, negative outlook.
	27 Indonesia	Moody's rating outlook changed to negative.
Nov	25 Korea	Standard and Poors rating downgraded, negative outlook.
	27 Korea	Moody's rating downgraded with stable outlook.
	27 Thailand	Moody's rating downgraded with negative outlook.
Dec	10 Korea	Moody's rating downgraded, on review for further downgrade.
	11 Korea	Standard and Poors rating downgraded, negative outlook.
	21 Various	Moody's rating confirmed for China, Hong Kong, Japan, The Philippines, Singapore and Taiwan.
	21 Various	Moody's ratings downgraded for Indonesia, Korea, Malaysia and Thailand.
	22 Korea	Standard and Poors rating downgraded, negative outlook.
	23 Malaysia	Standard and Poors rating downgraded, negative outlook.
	31 Indonesia	Standard and Poors rating downgraded, negative outlook.

Table 11: Chronology of the Asian crisis - key rating events 1998.

Date	Country	Event
1998		
Jan	8 India	Moody's rating on review for downgrade.
	8 Thailand	Standard and Poors rating downgraded, negative outlook.
	9 Indonesia	Moody's and Standard and Poors ratings downgraded.
	Korea	Moody's rating on review for downgrade.
	16 Korea	Standard and Poors rating changed to developing.
	27 Indonesia	Standard and Poors rating downgraded, negative outlook.
	28 Singapore	Moody's rating confirmed, stable outlook.
Feb	2 China	Moodys rating changed to negative outlook.
	5 Malaysia	Moodys rating changed to negative outlook.
	7 Hong Kong	Moodys rating changed to negative outlook.
	18 Korea	Standard and Poors rating upgraded, stable outlook.
	23 The Philippines	Standard and Poors outlook changed from stable to negative.
Mar	11 Indonesia	Standard and Poors rating downgraded, negative outlook.
	20 Indonesia	Moody's rating downgraded with stable outlook.
	30 Korea	Moody's rating confirmed.
Apr	2 Japan	Moodys rating changed to negative outlook.
	17 Malaysia	Standard and Poors rating downgraded, stable outlook.
May	15 Indonesia	Standard and Poors rating downgraded, negative outlook.
	22 India	Standard and Poors outlook changed from stable to negative.
Jun	4 Malaysia	Moody's rating on review for downgrade.
	19 India	Moody's rating downgraded with stable outlook.
	22 Honk Kong	Standard and Poors outlook changed from stable to negative.
Jul	16 China	Standard and Poors outlook changed from stable to negative.
	23 Japan	Moodys rating changed to negative outlook.
	23 Malaysia	Moody's rating downgraded with stable outlook.
	24 Malaysia	Standard and Poors rating downgraded, negative outlook.

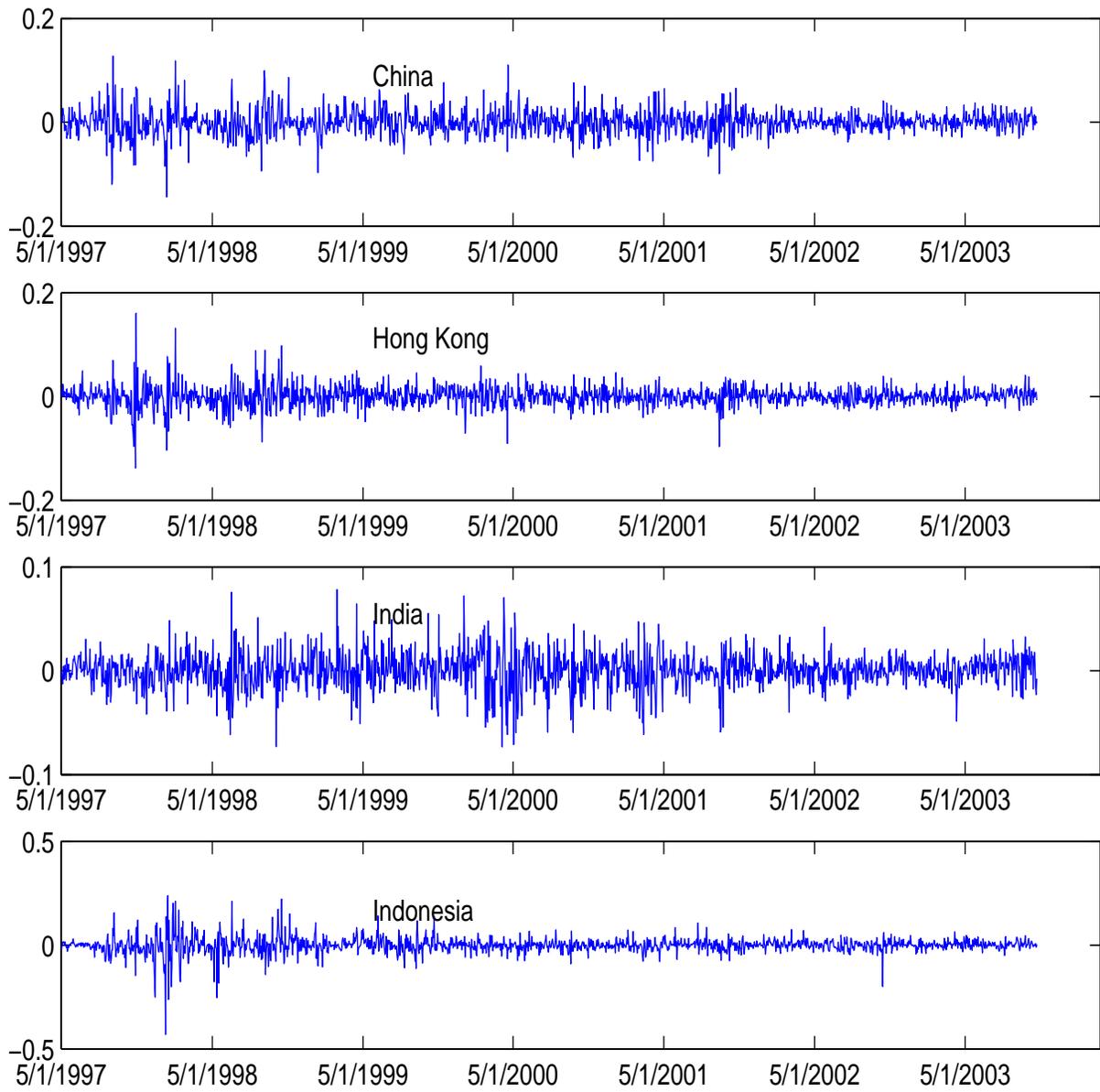


Figure 5: *Daily continuously compounded stock index returns of selected countries: April 30, 1997 to October 22, 2003*

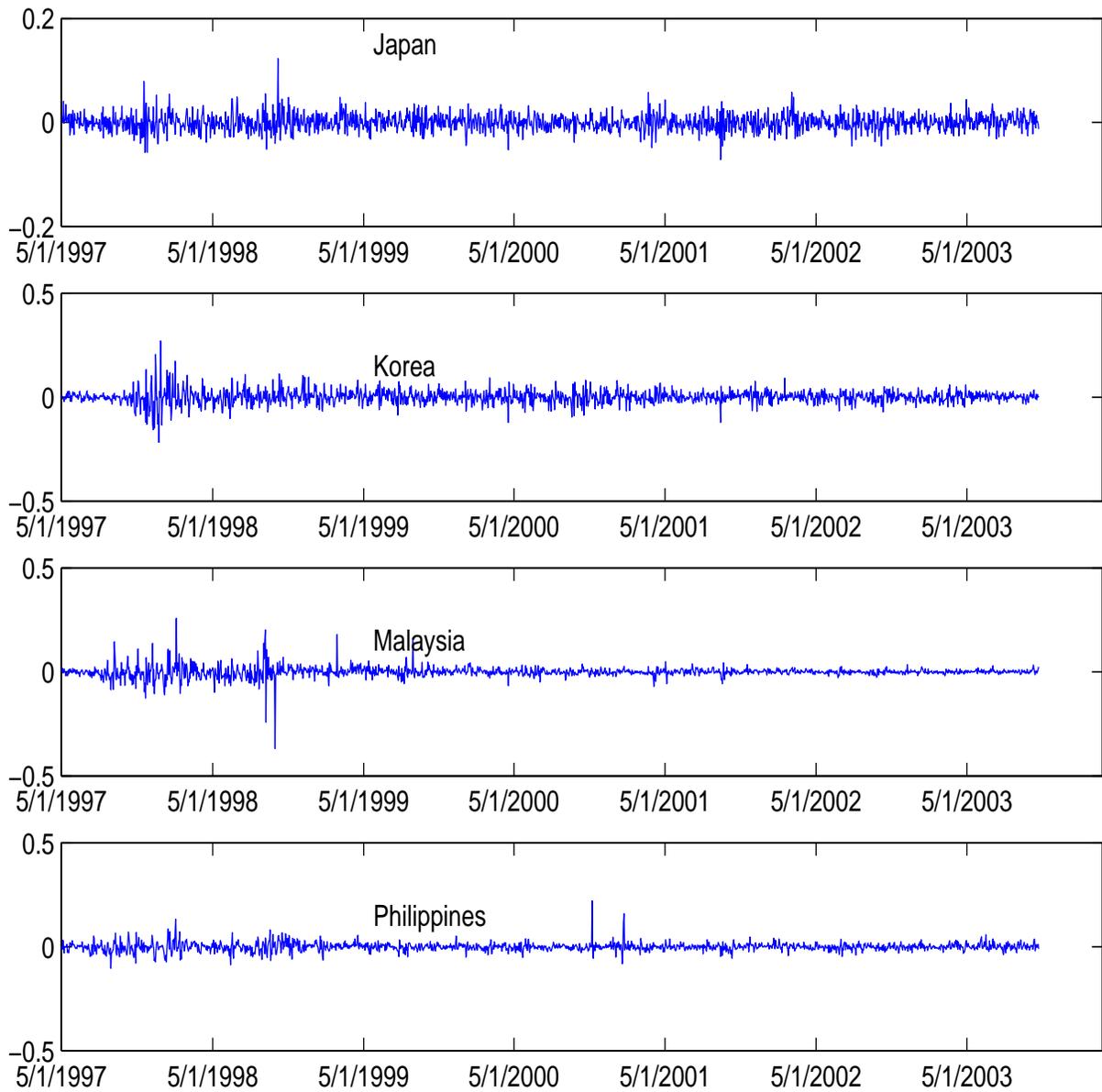


Figure 6: *Daily continuously compounded stock index returns of selected countries: April 30, 1997 to October 22, 2003*

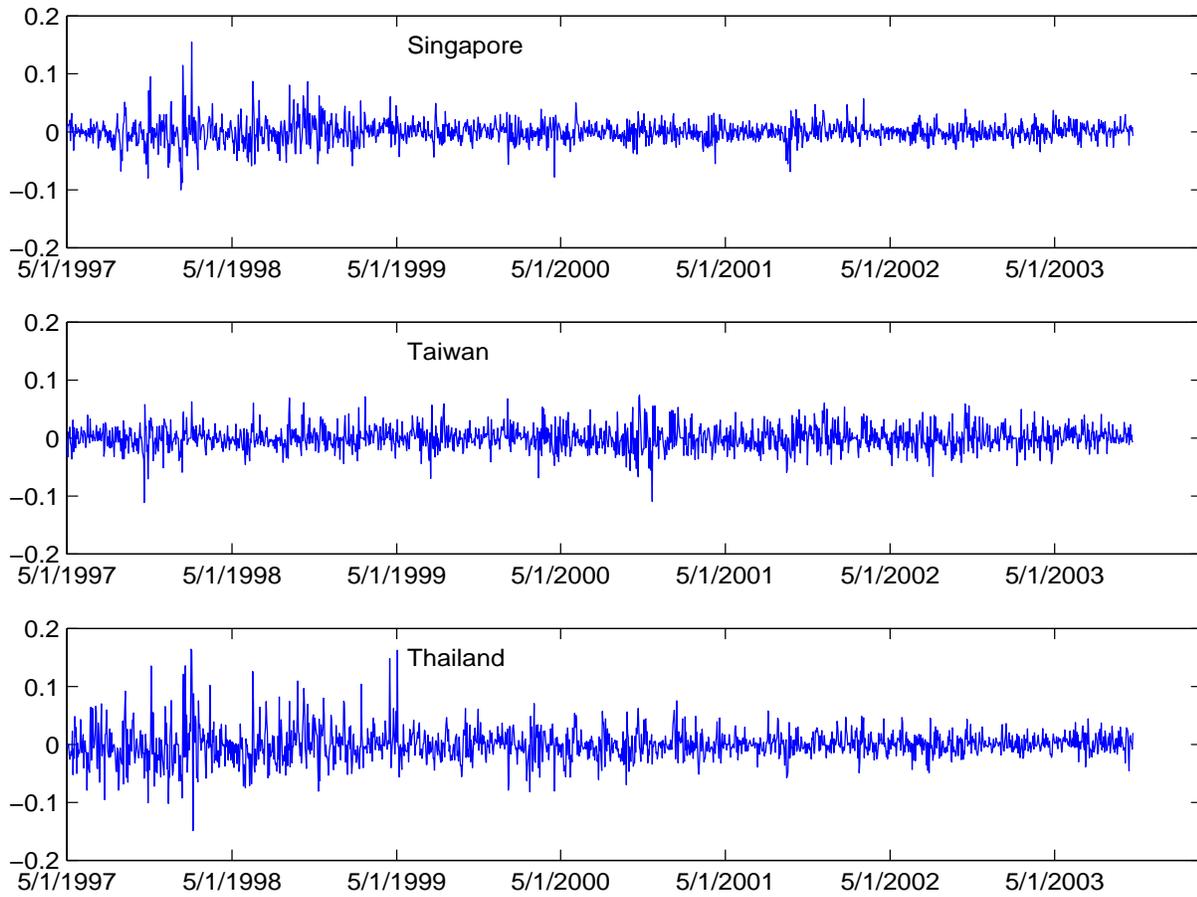


Figure 7: *Daily continuously compounded stock index returns of selected countries: April 30, 1997 to October 22, 2003*

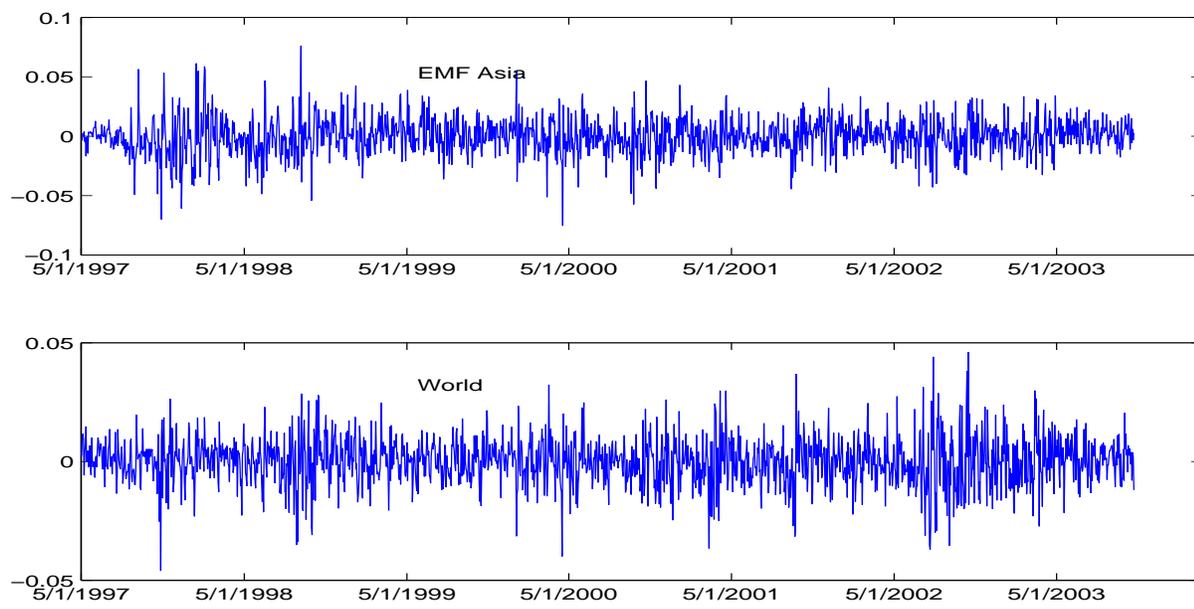


Figure 8: *Daily continuously compounded MSCI WORLD and MSCI Emerging Markets Free (EMF) Asia return indices: April 30, 1997 to October 22, 2003*