A Comparison of Seven Crises*

Renée Fry[%], Yu Ling Hsiao[%] and Chrismin Tang[+,%]

[%]CAMA, RSE, Australian National University
Canberra, ACT, Australia, 0200

[+]La Trobe University
Bundoora, Victoria, Australia, 3086

October 2010

Abstract

Episodes of extraordinary turbulence in global financial markets are examined during seven financial market crises ranging from Asia in 1997-98 to the most recent global financial crisis of 2007-10. The analysis focuses on equity markets captured by daily movements in returns for twelve countries using contagion tests for changes in dependence structures amongst asset markets, namely through correlation and coskewness. The results show substantial contagion from the global financial crisis. Other US sourced crises are not systemic, and emerging market crises transmit equally through correlation channels, but affect those least expected to be affected through higher order channels, indicating that more than just correlation channels should be considered in understanding crisis transmission.

Keywords: Contagion testing; Correlation; Coskewness; Asian crisis, Russian crisis, LTCM crisis, Brazil crisis, dot-com crisis, Argentinean crisis, global financial crisis

*The authors thank Vance Martin for input on the work on which this paper is built. Fry and Tang acknowledge funding from ARC grant DP0985783. Corresponding author is Renée Fry, email: renee.fry@anu.edu.au. Other authors' email addresses chrismin.tang@latrobe.edu.au; yu.hsiao@anu.edu.au.

1 Introduction

From an historical perspective, financial market crises are seemingly common place. To illustrate, equity price data for twelve countries are presented in Figure 1 over the period from September 1, 1995 to April 29, 2010. The shaded areas on this diagram indicate a period of crisis in some equity market around the globe, with the crises originating in diverse regions including Asia, Russia, the US and Latin America. The figure shows how dramatically markets can plummet when a crisis occurs, and also illustrates the connectedness of markets of equity markets as falls occur simultaneously. Yet anecdotally it is the case that crises appear to take policy makers, financial and economic systems by surprise.

Understanding the nature of shock transmission is crucial to optimal policy choices by governments, central banks and prudential regulators, as well as to portfolio management by financial market participants. The response of policy makers to crises and the regulatory structures designed to avoid or dampen the transmission of future crises are affected by whether linkages across markets are understood and stable, or whether new linkages between markets arise in the crisis period. The former types of linkages are consistent with transmission occurring through fundamentals and the latter with contagion. Determining the difference between these is complicated by the increase in volatility that is consistent with crisis periods as shown in Figure 2 which expresses the data of Figure 1 in percentage returns.

This paper applies a new class of tests for contagion developed in Fry, Martin and Tang (2010) to seven financial markets crises across twelve equity markets. The tests for contagion draw on the idea that the distribution of asset returns during financial crises can switch from negative to positive skewness where risk averse agents prefer positive to negative skewness, and so the lower average returns occurring in financial crises may be explained by agents trading-off lower average returns for positive skewness (Ingersoll, 1990; Harvey and Siddique, 2000; Fry, Martin and Tang, 2010). The multivariate version of this relationship connecting markets as agents adjust their cross market risk preferences is reflected in properties such as coskewness, where there is a relationship between the volatility in market i and the average returns of market j or vice versa. Again, in a crisis, as investors become increasingly risk averse, they prefer positive to negative coskewness.

Contagion here is referred to as a significant change in the comoments of a distribution of equity returns such as correlation or coskewness. The correlation contagion tests extend those of King and Wadhwani (1990) and subsequently Forbes and Rigobon (2002) who develop a test for contagion based on testing for a significant increase in cross market correlations during a crisis period compared to a non crisis period. If correlations of shocks between countries increase in a crisis compared to a non crisis period, then the nature of the transmission of financial market shocks has changed and there is evidence of contagion. The coskewness tests represent a new class of tests, but are related in spirit to the work in Yuan (2005) and Guidolin and Timmerman (2009) who focus on the role of skewness and/or kurtosis preferences in understanding asset prices given investor preferences or behavior.

The financial market crises considered include the 1997-1998 Asian financial crisis, the 1998 Russian crisis (sovereign debt default), the 1998 near-default of the US hedge fund Long Term Capital Management (LTCM), the 1999 Brazilian devaluation, the dotcom crisis of 2000 (collapses of speculative bubbles), the Argentinean crisis in 2001-2002 and the 2007-2010 global financial crisis. The work is related to Dungey et al. (2009) in theme, but different in framework, which explores whether or not financial market crises are alike in equity and bond markets. This paper explores this idea further by comparing transmission channels of crises through the higher order comoments, with a focus on equity markets.

There are several main empirical findings. First, the global financial crisis is indeed different and more widespread in terms of the transmission of contagion compared to the other financial market crises of the sample. Second, it is broadly not the case that crises beginning in the major financial centre of the US have important consequences through the channels of contagion for the rest of the world. The little contagion evident in the LTCM and dotcom crises sourced in the US suggests that shocks in a well integrated market do not result in surprise transmissions, providing further support that the global financial crisis is indeed different to past crises. Third, the emerging market crises in the sample with the exception of Argentina reveal that about two thirds of countries in the sample are affected by one channel of contagion during crises. Further, there is evidence that contagion falls evenly over the three types of crisis transmission channels where it exists, reiterating Fry, Martin and Tang (2010) that more than just the correlation based channel needs to be examined. It also appears that it is more likely that the markets expected not to have linkages with the source country are more likely to be affected through the higher order channels.

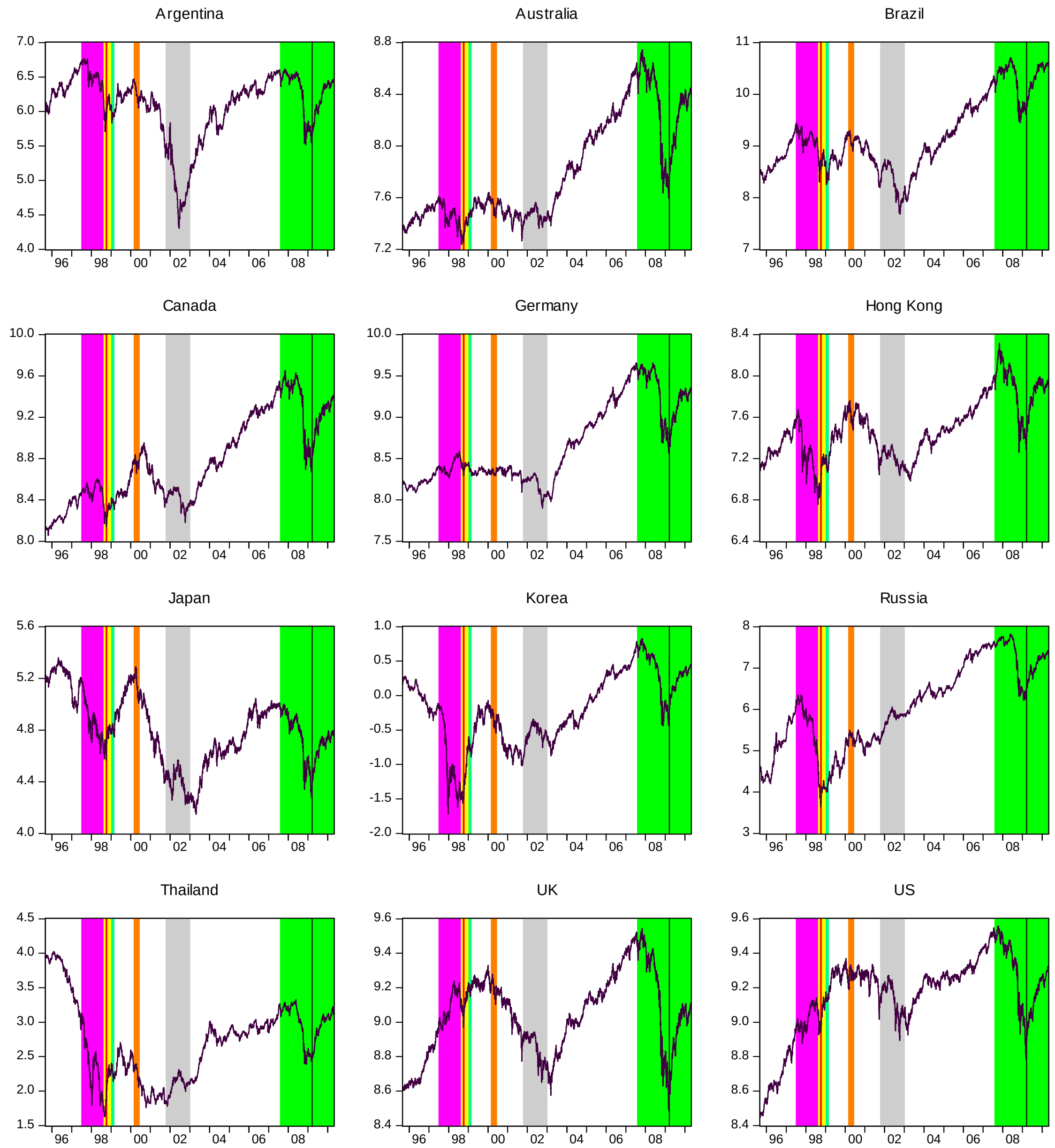

Figure 1: Daily equity prices (natural logs) - September 1, 1995-April 29, 2010. The shaded areas refer to episodes of crisis in international equity markets. These are (i) the Asian financial crisis (October 17, 1997 to May 18, 1998); (ii) the Russian bond default and the LTCM crisis (Russia: August 17, 1998 to December 31, 1998; LTCM: September 23, 1998 to October 15, 1998); (iii) the Brazilian crisis (January 7, 1999 to February 25, 1999), (iv) the dot-com crisis (February 28, 2000 to June 7, 2000); (v) the Argentinean crisis (October 11, 2001 to December 31, 2002); and (iv) the global financial crisis (July 26, 2007 to April 29, 2010). The solid vertical line indicates a potential regime change in the global financial crisis on March 9, 2009.

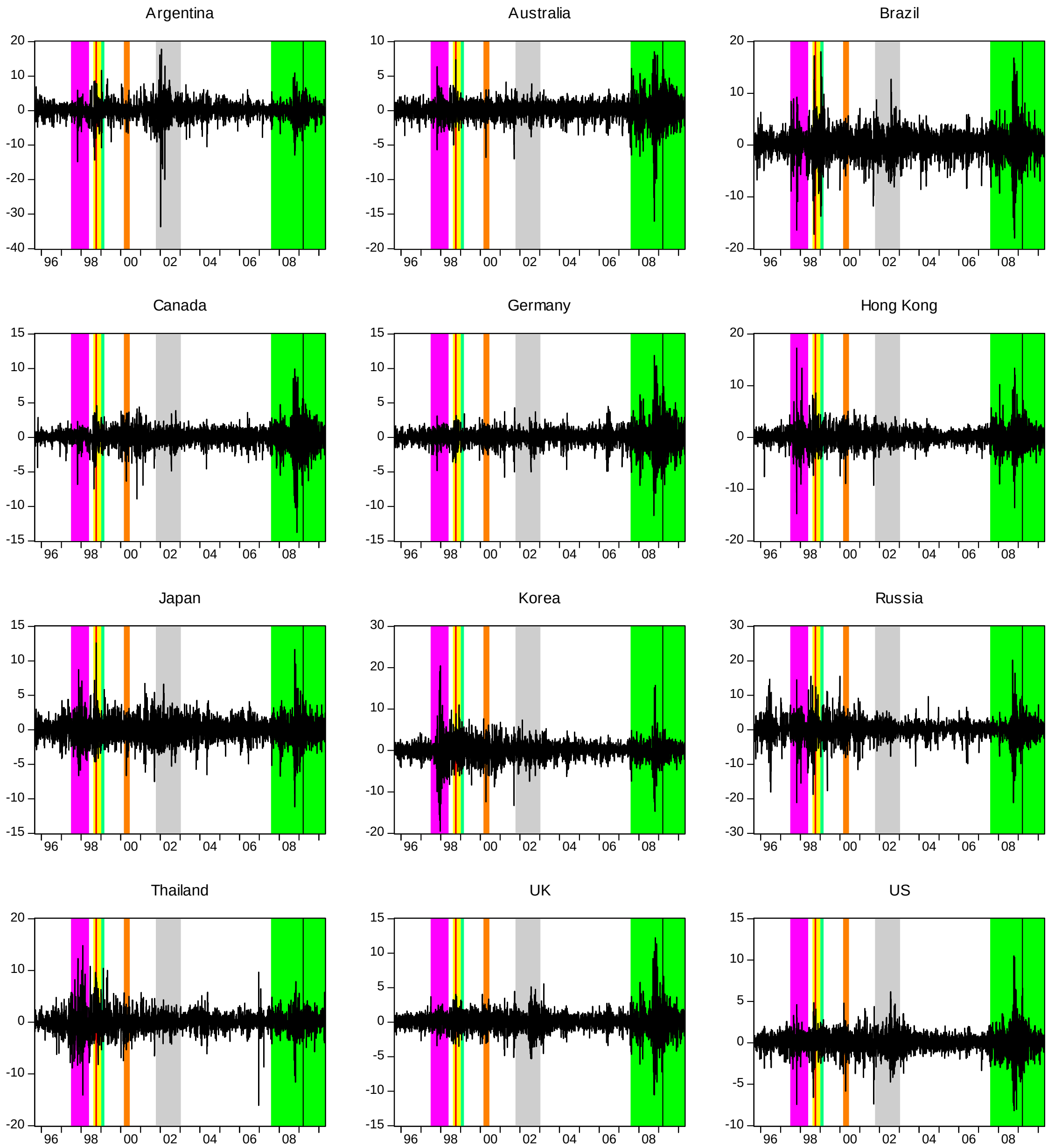

Figure 2: Daily equity price returns (percent) - September 4, 1995-April 29, 2010. The shaded areas refer to episodes of crisis in international equity markets. These are (i) the Asian financial crisis (October 17, 1997 to May 18, 1998); (ii) the Russian bond default and the LTCM crisis (Russia: August 17, 1998 to December 31, 1998; LTCM: September 23, 1998 to October 15, 1998); (iii) the Brazilian crisis (January 7, 1999 to February 25, 1999), (iv) the dot-com crisis (February 28, 2000 to June 7, 2000); (v) the Argentinean crisis (October 11, 2001 to December 31, 2002); and (iv) the global financial crisis (July 26, 2007 to April 29, 2010). The solid vertical line indicates a potential regime change in the global financial crisis on March 9, 2009.

Finally, the high incidence of contagion to developed markets in the Argentinean crisis probably reflects the fundamental structural change which occurred in Argentina with the abolishment of the currency board in 2002.

The rest of this paper proceeds as follows. Section 2 provides an overview of the portfolio model of risk developed in Fry, Martin and Tang (2010) which motivates the inclusion of coskewness in determining excess asset returns. Section 3 specifies the contagion tests based on changes in correlation and coskewness, and also examines the finite sample properties of the tests. Section 4 compares the past seven crises in terms of the contagion channels operating. Concluding comments are contained in Section 5.

2 A Portfolio Model of Risk

Fry, Martin and Tang (2010) present a portfolio model of higher order moments using a stochastic discount factor framework to derive an equilibrium pricing equation of excess returns to motivate the role of higher order moments including skewness and coskewness during crisis periods. The model builds on the work of Harvey and Siddique (2000), extending the mean-variance framework where the expected excess return on assets is expressed in terms of risk prices which are a function of the risk preferences of investors, and risk quantities which are a function of higher order conditional moments including skewness and coskewness.

Intertemporal asset pricing theory gives the Euler equation for the stochastic discount factor m_{t+1} as

$$m_{t+1} = \frac{\beta u'(w_{t+1})}{u'(w_t)} \tag{1}$$

for the equilibrium pricing equation

$$E\left[m_{t+1}\left(r_{i,t+1} - \mu_{i,t+1}\right) \middle| s_{t+1}\right] = 0. \tag{2}$$

β is the time discount rate, $u(\cdot)$ is the utility of wealth w, $r_{i,t+1}$ is the return on asset i, $E_t[\cdot]$ is the conditional expectations operator based on information at time t and the states of nature s_{t+1} at $t+1$. The conditional expectation of returns at time $t+1$ is

$$\mu_{i,t+1} = E\left[r_{i,t+1} | s_{t+1}\right]. \tag{3}$$

The marginal utility of wealth $u'(w_{t+1})$ in (1) can be expressed as

$$u'(w_{t+1}) = u'\left(\left(1 + \sum_{i=1}^{N} \alpha_i r_{i,t+1}\right) w_t\right), \tag{4}$$

with

$$\sum_{i=1}^{N} \alpha_i r_{i,t+1} = r_{p,t+1} \tag{5}$$

representing the return on a N asset portfolio $r_{p,t+1}$ with the weight of each asset α_i.

The marginal utility of wealth in (4) can be approximated by a Taylor series expansion around the conditional expectation of returns $\mu_{i,t+1}$ where for $N = 2$,

$$\begin{aligned} u'(w_{t+1}) \simeq\ & u'\left(w_t + w_t\mu_{p,t+1}\right) + u''\left(w_t + w_t\mu_{p,t+1}\right)\alpha_1 w_t\left(r_{1,t+1} - \mu_{1,t+1}\right) \\ & + u''\left(w_t + w_t\mu_{p,t+1}\right)\alpha_2 w_t\left(r_{2,t+1} - \mu_{2,t+1}\right) \\ & + \frac{1}{2}u'''\left(w_t + w_t\mu_{p,t+1}\right)\alpha_1^2 w_t^2\left(r_{1,t+1} - \mu_{1,t+1}\right)^2 \\ & + \frac{1}{2}u'''\left(w_t + w_t\mu_{p,t+1}\right)\alpha_2^2 w_t^2\left(r_{2,t+1} - \mu_{2,t+1}\right)^2 \\ & + \frac{1}{2}u'''\left(w_t + w_t\mu_{p,t+1}\right)\alpha_1\alpha_2 w_t^2\left(r_{1,t+1} - \mu_{1,t+1}\right)\left(r_{2,t+1} - \mu_{2,t+1}\right) + o(w_t), \end{aligned} \tag{6}$$

where $o(w_t)$ represents the higher order terms in the Taylor series expansion and $\mu_{p,t+1}$ is the conditional expected return on the portfolio.

From (2) and (3),

$$E\left[m_{t+1}|\, s_{t+1}\right] + E\left[m_{t+1}\left(r_{i,t+1} - \mu_{i,t+1}\right)\middle|\, s_{t+1}\right] + E\left[m_{t+1}|\, s_{t+1}\right]\mu_{i,t+1} = 1,$$

or

$$1 + \frac{E\left[m_{t+1}\left(r_{i,t+1} - \mu_{i,t+1}\right)\middle|\, s_{t+1}\right]}{E\left[m_{t+1}|\, s_{t+1}\right]} + \mu_{i,t+1} = \frac{1}{E\left[m_{t+1}|\, s_{t+1}\right]}. \tag{7}$$

From Campbell, Lo and MacKinlay (1997)

$$E\left[m_{t+1}|\, s_{t+1}\right] = \frac{1}{1 + r_{f,t+1}},$$

where $r_{f,t+1}$ is the risk free rate of interest. From this (7) becomes

$$\mu_{i,t+1} - r_{f,t+1} = -\left(1 + r_{f,t+1}\right)E\left[m_{t+1}\left(r_{i,t+1} - \mu_{i,t+1}\right)\right].$$

From (1) and (6) with higher order moments suppressed,

$$\begin{aligned} \mu_{i,t+1} - r_{f,t+1} =\ & \phi_1 E\left[\left(r_{1,t+1} - \mu_{1,t+1}\right)\left(r_{i,t+1} - \mu_{i,t+1}\right)\middle|\, s_{t+1}\right] \\ + & \phi_2 E\left[\left(r_{2,t+1} - \mu_{2,t+1}\right)\left(r_{i,t+1} - \mu_{i,t+1}\right)\middle|\, s_{t+1}\right] \\ + & \phi_3 E\left[\left(r_{1,t+1} - \mu_{1,t+1}\right)^2\left(r_{i,t+1} - \mu_{i,t+1}\right)\middle|\, s_{t+1}\right] \\ + & \phi_4 E\left[\left(r_{2,t+1} - \mu_{2,t+1}\right)^2\left(r_{i,t+1} - \mu_{i,t+1}\right)\middle|\, s_{t+1}\right] \\ + & \phi_5 E\left[\left(r_{1,t+1} - \mu_{1,t+1}\right)\left(r_{2,t+1} - \mu_{2,t+1}\right)\left(r_{i,t+1} - \mu_{i,t+1}\right)\middle|\, s_{t+1}\right], \end{aligned} \tag{8}$$

where

$$\begin{aligned}
\phi_1 &= -\frac{\beta u''\left(w_t + w_t\mu_{p,t+1}\right)\left(1 + r_{f,t+1}\right)\alpha_1 w_t}{u'\left(w_t\right)} \\
\phi_2 &= -\frac{\beta u''\left(w_t + w_t\mu_{p,t+1}\right)\left(1 + r_{f,t+1}\right)\alpha_2 w_t}{u'\left(w_t\right)} \\
\phi_3 &= -\frac{\beta u'''\left(w_t + w_t\mu_{p,t+1}\right)\left(1 + r_{f,t+1}\right)\alpha_1^2 w_t^2}{2u'\left(w_t\right)} \qquad (9)\\
\phi_4 &= -\frac{\beta u'''\left(w_t + w_t\mu_{p,t+1}\right)\left(1 + r_{f,t+1}\right)\alpha_2^2 w_t^2}{2u'\left(w_t\right)} \\
\phi_5 &= -\frac{\beta u'''\left(w_t + w_t\mu_{p,t+1}\right)\left(1 + r_{f,t+1}\right)\alpha_1\alpha_2 w_t^2}{2u'\left(w_t\right)}.
\end{aligned}$$

Equation (8) is the equilibrium pricing equation which shows that the risk of an asset is decomposed in terms of risk prices, as given by ϕ_i, and risk quantities, as given by the conditional expectations. The risk prices are expressed in terms of the various risk aversion measures arising from the utility function of the investor, the discount parameter β, the share of the asset in the portfolio α_i, and the risk free interest rate r_f. The risk quantities contain the second moment terms, skewness $E\left[\left.\left(r_{2,t+1} - \mu_{2,t+1}\right)^3\right| s_{t+1}\right]$ and coskewness, $E\left[\left.\left(r_{1,t+1} - \mu_{1,t+1}\right)^2\left(r_{2,t+1} - \mu_{2,t+1}\right)\right| s_{t+1}\right]$, $E\left[\left.\left(r_{1,t+1} - \mu_{1,t+1}\right)\left(r_{2,t+1} - \mu_{2,t+1}\right)^2\right| s_{t+1}\right]$.

This model provides the relationship between excess asset returns and risk quantities, which include measures based on covariances and coskewness. The definition of contagion adopted in this paper can be interpreted as comovements in asset returns not due to changes in fundamentals. The statistics examined in this paper implicitly focus on the changes in the risk quantities at the higher order level, and condition on these fundamentals, as well as the state of nature, s_{t+1}.

3 Tests of Changes in Market Linkages

This section specifies the three tests of financial market contagion as derived in Fry, Martin and Tang (2010). These tests are derived from a new family of bivariate distributions based on the generalized exponential distribution of Cobb, Koppstein and Chen (1983) and Lye and Martin (1993). In the framework, the bivariate normal distribution is extended to allow for higher order comoments and Lagrange Multiplier Tests derived as the basis of the tests for contagion. Full derivations can be found in Fry, Martin and Tang (2010). The first test of contagion is a correlations-based test similar to that used in Forbes and Rigobon (2002) and refined in Fry, Martin and Tang (2010) which tests for changes in correlations across different sample periods. The second and third tests identify contagion as a significant change in coskewness across countries during periods of financial market instability compared to normal times. These two tests are based on two different forms of coskewness. In the notation that follows, the non crisis and crisis periods data are denoted by x and y, and the non crisis and crisis sample periods are T_x and T_y respectively. The crisis source asset market is denoted by i while j represents the recipient market.

3.1 Correlation Contagion Test

Correlation coefficients calculated for crisis periods $\left(\widehat{\rho}_y\right)$ may be biased upwards because of increased volatility in market returns in the source country during periods of market turmoil. Forbes and Rigobon (2002) show how this bias can be removed by adjusting the unconditional correlation coefficient between the source and recipient countries for the crisis period. The crisis period correlation coefficient adjusted for heteroskedasticity is given by

$$\widehat{\nu}_{y|x_i} = \frac{\widehat{\rho}_y}{\sqrt{1+\delta\left(1-\widehat{\rho}_y^2\right)}}, \tag{10}$$

where $\widehat{\nu}_{y|x_i}$ is the adjusted correlation coefficient in the crisis period. The denominator of $\widehat{\nu}_{y|x_i}$ consists of $\delta = \dfrac{s_{y,i}^2 - s_{x,i}^2}{s_{x,i}^2}$ which is the proportionate change in the volatility of returns in the source equity market i, where $s_{x,i}^2$ and $s_{y,i}^2$ are the sample variances of equity returns in market i during the non crisis and crisis periods.

The statistic for contagion based on the significance of a change in the adjusted crisis period correlation compared to a non crisis period correlation $(\widehat{\rho}_x)$ from i to j can be represented as

$$CR(i \rightarrow j) = \left(\frac{\widehat{\nu}_{y|x_i} - \widehat{\rho}_x}{\sqrt{Var\left(\widehat{\nu}_{y|x_i} - \widehat{\rho}_x\right)}}\right)^2, \tag{11}$$

where

$$Var\left(\widehat{\nu}_{y|x_i} - \widehat{\rho}_x\right) = Var\left(\widehat{\nu}_{y|x_i}\right) + Var\left(\widehat{\rho}_x\right) - 2Cov\left(\widehat{\nu}_{y|x_i}, \widehat{\rho}_x\right) \quad (12)$$

$$Var\left(\widehat{\nu}_{y|x_i}\right) = \frac{1}{2}\frac{(1+\delta)^2}{\left[1+\delta\left(1-\rho_y^2\right)\right]^3}\left[\frac{1}{T_y}\left(\left(2-\rho_y^2\right)\left(1-\rho_y^2\right)^2\right) + \frac{1}{T_x}\left(\rho_y^2\left(1-\rho_y^2\right)^2\right)\right] \quad (13)$$

$$Var\left(\widehat{\rho}_x\right) = \frac{1}{T_x}\left(1-\rho_x^2\right)^2 \quad (14)$$

$$Cov\left(\widehat{\nu}_{y|x_i}, \widehat{\rho}_x\right) = \frac{1}{2}\frac{1}{T_x}\frac{\rho_y\rho_x\left(1-\rho_y^2\right)\left(1-\rho_x^2\right)(1+\delta)}{\sqrt{\left[1+\delta\left(1-\rho_y^2\right)\right]^3}}. \quad (15)$$

The standard error in equation (11) derives from the asymptotic distribution of the estimated correlation coefficient, which is given in Fry, Martin and Tang (2010). This form of correlation test is slightly different to that in Forbes and Rigobon (2002) as the data period is non-overlapping and is actually the square of the statistic thereby making this a two-sided test. Forbes and Rigobon (2002) suggest a one sided test, testing only for an increase in correlation.

In testing for a significant change in correlation, the null hypothesis of no contagion is constructed as

$$H_0 : \widehat{\nu}_{y|x_i} = \rho_x,$$

against the alternative hypothesis of contagion between two equity markets, which is given as

$$H_1 : \widehat{\nu}_{y|x_i} \neq \rho_x.$$

Under the null hypothesis of no contagion, the correlation test of contagion is asymptotically distributed as

$$CR(i \to j) \xrightarrow{d} \chi_1^2. \quad (16)$$

3.2 Coskewness Contagion Test

The second test of contagion considered is the change in the coskewness test of Fry, Martin and Tang (2010) where the coskewness coefficient of a stable period is compared with the coskewness coefficient of the crisis period in order to identify statistically significant changes in coskewness between the two periods. Coskewness is a third moment and can take two forms. The first form of coskewness is denoted $\widehat{\psi}_x\left(r_i^1, r_j^2\right)$ and is given by

$$\widehat{\psi}_x\left(r_i^1, r_j^2\right) = \frac{1}{T}\sum_{t=1}^{T}\left(x_i - \widehat{\mu}_i\right)^1\left(x_j - \widehat{\mu}_j\right)^2. \quad (17)$$

This form of coskewness is a function of the relationship between the (demeaned) level of the equity returns of country $(x_i - \widehat{\mu}_i)^1$ and the volatility of the demeaned equity returns of market j $\left(x_j - \widehat{\mu}_j\right)^2$.

The second form of coskewness is $\widehat{\psi}_x\left(r_i^2, r_j^1\right)$, where

$$\widehat{\psi}_x\left(r_i^2, r_j^1\right) = \frac{1}{T}\sum_{t=1}^{T}(x_i - \widehat{\mu}_i)^2\left(x_j - \widehat{\mu}_j\right)^1. \quad (18)$$

This form of coskewness is a function of the volatility of the (demeaned) equity returns of the source market i $(x_i - \widehat{\mu}_i)^2$ and the level of the (demeaned) equity market returns of x_j $\left(x_j - \widehat{\mu}_j\right)^1$, the recipient country.

Analogous to the correlation test for contagion, the coskewness test for contagion tests for a change in the distribution of the returns across a non crisis and crisis period. A significant change in the coskewness coefficient during a financial crisis is a form of contagion through the third order comoments.

Two types of coskewness form the basis of the two tests of contagion, denoted CS_1 and CS_2. The Fry, Martin and Tang (2010) tests of contagion from i (a source market) to j (a recipient market) are given by

$$CS_1\left(i \to j; r_i^1, r_j^2\right) = \left(\frac{\widehat{\psi}_y\left(r_i^1, r_j^2\right) - \widehat{\psi}_x\left(r_i^1, r_j^2\right)}{\sqrt{\dfrac{4\widehat{\nu}_{y|x_i} + 2}{T_y} + \dfrac{4\widehat{\rho}_x^2 + 2}{T_x}}}\right)^2, \quad (19)$$

$$CS_2\left(i \to j; r_i^2, r_j^1\right) = \left(\frac{\widehat{\psi}_y\left(r_i^2, r_j^1\right) - \widehat{\psi}_x\left(r_i^2, r_j^1\right)}{\sqrt{\dfrac{4\widehat{\nu}_{y|x_i} + 2}{T_y} + \dfrac{4\widehat{\rho}_x^2 + 2}{T_x}}}\right)^2, \quad (20)$$

where

$$\widehat{\psi}_y\left(r_i^m, r_j^n\right) = \frac{1}{T_y}\sum_{t=1}^{T_y}\left(\frac{y_{i,t} - \widehat{\mu}_{y_i}}{\widehat{\sigma}_{y_i}}\right)^m\left(\frac{y_{j,t} - \widehat{\mu}_{y_j}}{\widehat{\sigma}_{y_j}}\right)^n, \quad (21)$$

$$\widehat{\psi}_x\left(r_i^m, r_j^n\right) = \frac{1}{T_x}\sum_{t=1}^{T_x}\left(\frac{x_{i,t} - \widehat{\mu}_{x_i}}{\widehat{\sigma}_{x_i}}\right)^m\left(\frac{x_{j,t} - \widehat{\mu}_{x_j}}{\widehat{\sigma}_{x_j}}\right)^n. \quad (22)$$

The terms μ_{y_i} and μ_{y_j} are the mean of equity returns of market i and j and $\sigma_{y_i}$and σ_{y_j} are the standard errors of equity returns of market i and j respectively. The differences in the tests are dependent on whether the equity market at the source of the crisis is expressed in accordance with the levels of the returns (the first coskewness test) or the squared returns (the second coskewness test) in computing coskewness.

To test for contagion based on (significant change in) coskewness, the null hypothesis of no contagion is constructed as the equality of the relevant statistic across non crisis and non crisis periods while the alternative hypothesis of contagion is constructed as no significant change during the crisis period.

The null and alternative hypotheses using statistic CS_1 and CS_2 are given by

$$\begin{aligned} H_0 &: \psi_y(r_i^m, r_j^n) = \psi_x(r_i^m, r_j^n), \\ H_1 &: \psi_y(r_i^m, r_j^n) \neq \psi_x(r_i^m, r_j^n). \end{aligned}$$

Under the null hypothesis of no contagion, the coskewness test of contagion is asymptotically distributed as

$$CS_1 (i \rightarrow j), CS_2 (i \rightarrow j) \xrightarrow{d} \chi_1^2. \tag{23}$$

3.3 Finite Sample Properties

This section calculates the critical values for the three tests of contagion (CR, CS_1 and CS_2) through several Monte Carlo experiments, with attention devoted to the duration of the crisis period T_y. Crisis periods vary in length but may be quite short raising the possibility of small sample issues in the tests developed to detect contagion. For example, in the empirical applications, the duration of the LTCM crisis is just $T_y = 17$ days, while for the global financial crisis the duration is $T_y = 718$.

To calculate the critical values for each test statistic under the null hypothesis of no contagion, a series of random samples of pre crisis and crisis period data are generated. The distribution of equity returns for the non-crisis and crisis periods under the null hypothesis are assumed to be bivariate normal with zero mean and respective variance-covariance matrix V_x and V_y of the source (r_i) and recipient (r_j) asset market. The variance-covariance matrices of the equity returns data in the sub periods are set at

$$V_x = \begin{bmatrix} 2.29 & 0.45 \\ 0.45 & 2.40 \end{bmatrix}, \; V_y = \begin{bmatrix} 11 & 3.5 \\ 3.5 & 5.9 \end{bmatrix}.$$

These matrices are determined from the data used in the empirical applications in the next section. For the non crisis period matrix (V_x) the average non crisis variance of the source and recipient returns is used for both assets. The covariances are determined by taking the average of the covariances of all asset pairs in the non crisis period. The crisis

Table 1:
Comparison of critical values for the tests of contagion based on the different sizes of the crisis sample period, for pre crisis samples of size $T_x = 2168$. Based on 100,000 replications.

	Correlation Test			Coskewness 1			Coskewness 2		
Sig. level/ T_y	0.025	0.05	0.1	0.025	0.05	0.1	0.025	0.05	0.1
15	6.12	4.72	3.31	4.57	3.39	2.32	4.42	3.22	2.27
30	5.26	4.08	2.87	4.88	3.63	2.49	5.06	3.71	2.52
60	5.12	3.91	2.74	4.84	3.63	2.51	4.95	3.77	2.69
90	5.14	3.95	2.72	4.89	3.76	2.63	4.9	3.72	2.56
150	5.21	3.88	2.72	5.08	3.68	2.65	5.11	3.91	2.67
200	4.94	3.82	2.71	5.05	3.81	2.62	5.18	3.93	2.76
250	5.07	3.85	2.68	4.84	3.69	2.61	5.03	3.78	2.71
350	4.97	3.96	2.73	5.06	3.85	2.70	5.41	4.04	2.84
600	5.05	3.85	2.64	5.08	3.93	2.77	4.89	3.74	2.68
700	5.21	3.97	2.73	4.94	3.79	2.73	4.81	3.73	2.66

period variance-covariance matrix (V_y) is determined by using the average variance of a source asset market along with the average variance of a recipient asset market, as well as the average covariance across all of the seven crisis periods considered. The increase in volatility of returns between the two periods is 380% for the source and 146% for the recipient. Under this parametrization, the correlations between the two assets are $\rho_x = 0.19$ and $\rho_y = 0.42$ respectively. The adjusted Forbes and Rigobon (2002) correlation coefficient is $\upsilon_y = 0.20$ which under the null of no contagion is close to the non crisis value of ρ_x.

The critical values are obtained for CR, $CS_1$and CS_2 for values of T_y spanning

$$T_y = \{15, 30, 60, 90, 150, 200, 250, 350, 600, 700\}.$$

The non crisis sample size is $T_x = 1472$ which is consistent with the number of observations in the non crisis period in the empirical examples.

The results of the Monte Carlo experiments using 100,000 replications are contained in Table 1. They show that as the crisis sample size increases, the distribution of equity returns tends to follow a χ^2_1 distribution. If $T_y \leq 30$, the test statistic tends to be biased and the critical values require adjusting following the first two rows of Table 1.

4 A Comparison of Seven Crises

This section applies the contagion tests outlined above to the equity markets in the seven most recent financial market crises spanning the crises of Asia, Russia, LTCM, Brazil, Dotcom, Argentina and the global financial crisis. The sample consists of daily equity price indices ($P_{i,t}$) expressed in US dollars collected for the twelve equity markets of Argentina, Australia, Brazil, Canada, Germany, Hong Kong, Japan, Russia, Korea, Thailand, the UK and the US. The data is collected from Datastream.[1] The sample period begins September 1, 1995 and ends April 27, 2010, a total of $T = 3822$ observations. Daily percentage equity returns of the i^{th} market are calculated as

$$R_{i,t} = 100\left(ln(P_{i,t}) - ln(P_{i,t-1})\right).$$

As is standard in the contagion literature, the data set is adjusted for interdependencies and market fundamentals by filtering the data with a VAR and then using the residuals of the VAR as the returns used in the calculation of the test statistics of Sections 3.1 and 3.2. The lag order is chosen following the results of the SC and HQ lag order selection criteria as shown in Table 2.

4.1 Crisis Period Dating

As the contagion tests are conditioned on a 'state' of nature s_t at any particular time, the dating of the crisis periods is an essential component in testing for contagion. The dating chosen for the seven crisis periods is contained in Table 3, and generally follows Dungey et al. (2009) which analyses the Russian, LTCM, Brazilian, dotcom, Argentinean and global financial crises. The principles of choosing the crisis dates are loosely that a trigger event marks the beginning of the crisis, and where possible, an event or a policy reform marks the end of a crisis. Often there is no consensus in the literature as to the dating of a crisis, although there is a body of work emerging where the dates of historical crises of different types are defined, particularly for banking crises (which is not necessarily applicable here). See for examples Caprio, Kingebiel,

[1] The mnemonics are: Argentina - Merval price index (ARGMERV(PI)~U$); Australia - S&P/ASX 200 Price index(ASX200I(PI)~U$); Brazil - Bovespa price index (BRBOVES(PI)~U$); Canada - S&P/TSX composite index (TTOCOMP(PI)~U$); Germany - MDAX Frankfurt price index (MDAXIDX(PI)~U$); Hong Kong - Hang Seng - price index (HNGKNGI(PI)~U$); Japan - NIKKEI 225 stock average - price index (JAPDOWA(PI)~U$); Korea - SE composite KOSPI price index (KORCOMP and the Korean Won to US $ (KO) exchange rate KOUSDSP); Russia - RTS Index (RSRTSIN(PI)~U$); Thailand - Bangkok SET - price index (BNGKSET(PI)~U$); the UK - FTSE 100 price index (FTSE100~U$); and Dow Jones Industrials Price index (DJINDUS(PI)).

Table 2:
Lag selection criteria.

Lag	LR		FPE		AIC		SC		HQ	
0	NA		12151.170		43.460		43.479		43.467	
1	2767.387		6324.009		42.807		43.062	*	42.897	*
2	452.515		6052.084		42.763		43.254		42.937	
3	438.132		5811.777	*	42.722	*	43.450		42.981	
4	227.640		5900.025		42.737		43.701		43.080	
5	323.417		5837.476		42.727		43.926		43.153	
6	248.326		5891.201		42.736		44.171		43.246	
7	234.774		5965.862		42.748		44.420		43.342	
8	258.097		6002.490		42.754		44.662		43.432	
9	238.049		6070.843		42.766		44.909		43.527	
10	197.616	*	6206.411		42.788		45.167		43.633	

*indicates the optimal lag choice

Laeven and Noguera (2005), Laeven and Valencia (2008), Reinhart and Rogoff (2008) and Reinhart (2010). The non crisis period (x_t) consists of all data not considered to be in crisis with the dates summarized at the bottom of the table. The non crisis dataset consists of $T_x = 2168$ observations.

The Asian crisis is also included in this paper and is the first crisis in the sample. This crisis is defined to occur over 20 October, 1997 to May 18, 1998 for a total of $T_y = 151$ observations. The starting date coincides with the speculative attack on the Hong Kong currency and equity markets. It is common to use October 20 as the start date of the crisis, with the alternative being the devaluation of the Thai baht in July, 1997 (see Corsetti et al., 2005 and Dungey, Fry and Martin, 2006, Forbes and Rigobon, 2002). As equity markets are the focus of this paper, the Hong Kong attack is the source here. The end date is chosen consistent with Baur and Fry (2009) and to avoid clashing with the Russian crisis period which occurs in August that same year.

The Russian crisis begins on August 17, 1998 and ends December 31, 1998. The Russian Government deferred bond repayments on this date, marking the beginning of extreme asset market volatility. The Russian crisis duration is $T_y = 99$. The LTCM crisis is linked to events in Russia and is nested within the Russian crisis period. The start of the LTCM crisis coincides with the Federal Reserve of New York bailout of

LTCM on September 23, 1998, and ends with the inter-FOMC interest rate cut on October 15. The crisis was contained to $T_y = 17$ days. See Dungey et al. (2006) for further crisis dating details as well as the Committee on the Global Financial System (1999).

The start of the Brazilian crisis is also marked by the devaluation of the real on January 15, 1999, however, the start date of the crisis is taken to be January 7, 1999, as in the week prior to the devaluation USD14billion in reserves was lost. The end of the crisis corresponds to a revised IMF program on February 25, 1999 which appeared to calm markets. The Brazilian crisis duration is $T_y = 36$ days.

The dotcom crisis corresponds to that chosen in Dungey (2009) et al. and is based on visual inspection of the equity returns. A large component of that paper is a sensitivity to the dating of crisis periods. The dotcom crisis extends from February 28, 2000 and ends June 7, 2000, for $T_y = 73$ days.

Apart from the global financial crisis, the Argentinean crisis is longest in duration at $T_y = 317$ days. The beginning is chosen to be October 11, 2001 following the introduction of the partial deposit freeze and capital controls (Cifarelli and Paladino (2004)). The end of the crisis is more difficult to pin down. Dungey et al. (2009) and Wälti and Weder (2008) use March 2005 which coincides with Argentina's return to the voluntary bond market. However, this dating is more consistent with events in the Argentinean bond market rather than equity markets. Data in Figure 3 shows the percentage excess returns in the US dollar denominated sovereign bond market for Argentina over the U.S. Treasury 10-year benchmark bond yield.[2] The figure shows several large spikes during the crisis in Argentina which correspond with the coupon dates after Argentinean sovereign debt went into default, with the price for these bonds declining because of uncertainty surrounding the scheduled coupon payment. Comparison with the data for Argentina in Figures 1 and 2 shows that the crisis in

[2] As bonds are not issued consistently in Argentina, it is not possible to derive a daily 10-year bond series. To circumvent this problem a 10 year bond issued near the start of the sample period is tracked over the sample period. For these bonds, the returns are computed using

$$b_t = -n\left(r_{n,t} - r_{n-1,t-1}\right),$$

where $r_{n,t}$ is the yield on a bond with term to maturity, $n = 10$ years, with the term to maturity, declining monotonically over the sample (see Campbell, Lo and MacKinlay, 1997 and Craine and Martin, 2008). As the bond matures before the end of the sample, and to avoid liquidity problems as the liquidity for the bond falls as it approaches maturity, another 10 year bond is chosen beginning July 1, 2004 and the bond is then tracked through the remaining part of the sample. Although this involves using bonds of differing maturities, by working with returns accounting for breaks instead of yields, or even yield changes, makes the returns data on bonds commensurate.

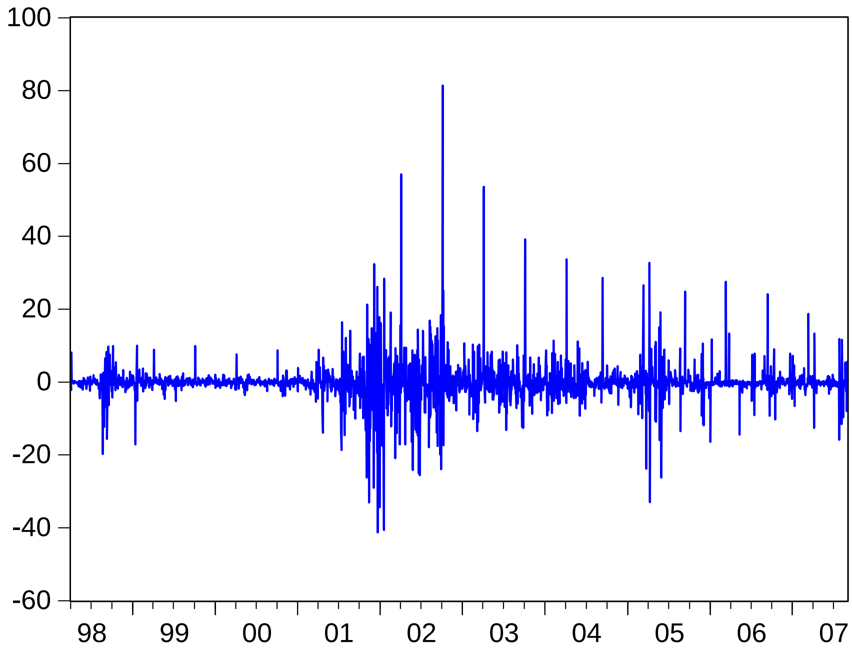

Figure 3: Daily bond percentage excess returns, expressed in US dollars, March 31, 1998 to December 31, 2007.

the bond market appeared to last for a relatively long time compared to that in the equity market. For equity markets the end date is taken to be December 31, 2002 and is determined by visual inspection. This period encompasses the collapse of the currency board in Argentina in 2002 during this time as well. See IMF (2003) for a comprehensive overview of the events in Argentina.

The global financial crisis is still arguably underway. History is not such that it is yet possible to judge that the crisis is over, or even perhaps that there is some degree of structural change in the dynamics of the crisis. The crisis is defined to span July 26, 2007 to April 27, 2007. The start date corresponds with Dungey et al. (2009), and is chosen to be prior to the collapse of Lehman brothers, as there were clear jitters in the market prior to that event. The end date corresponds to the date that the data was collected. The sample size for this crisis is $T_y = 718$ days. However, inspection of the equity data in Figures 1 and 2 shows a trough in in the US market in March of 2009, and the volatility characteristics around this time also appear to change. This is indicated by the vertical line on these figures. To determine whether or not the

Table 3:
Crisis and non crisis period dates.

Non and Crisis Periods	Start of period	End of period	Observations
Asia	20 October 1997	18 May 1998	151
Russia	17 August 1998	31 December 1998	99
LTCM	23 September 1998	15 October 1998	17
Brazil	7 January 1999	25 February 1999	36
Dotcom	28 February 2000	7 June 2000	73
Argentina	11 October 2001	31 December 2002	317
Global financial crisis	26 July 2007	27 April 2010	718
non crisis period dates*	4 September 1995	17 October 1997	555
	19 May 1998	16 August 1998	64
	1 January 1999	6 January 1999	4
	26 February 1999	27 February 2000	2
	8 June 2000	10 October 2001	350
	1 January 2003	25 July 2007	1193

* The non crisis periods takes all data not defined to be in crisis and concatenates it for calculation of the non crisis period statistics

dynamics of the global financial crisis change around this date, a sub period sensitivity analysis is undertaken with the sub periods split at March 9, 2009.

4.2 Contagion Channels During Crises

As a point of reference for understanding the nature of the change in the distribution of the correlation and coskewness statistics, the following tables provide relevant statistics on the non crisis and crisis data. Included in Table 4 and the first five columns of Table 6 are statistics on the mean, minimum, maximum, standard deviation and skewness for all markets for the non crisis and the crisis periods respectively. Table 5 and the last three columns of Table 6 contain the relationships between the markets which are in crisis in some point in the sample, including the (simple) correlation coefficients $(\rho_k,\ k = x, y)$, and the coskewness statistics $\widehat{\psi}_k\left(r_i^m, r_j^n\right)$.

The main points to note from these tables is that in the non crisis period, all countries reported values of negative skewness apart from Hong Kong, and Japan, which is close to zero. This result confirms investors actively investing in risky assets and being prepared to accept the risk of large losses in return for higher returns.

Returns for Canada exhibited the lowest value of skewness at -0.97. All markets except Thailand reported positive non crisis returns, with the emerging countries of Brazil and Russia reporting the highest returns and the highest volatility on average.

In the crisis periods it is common for the skewness coefficients to switch to being positive. During the Asian crisis all regional Asian countries of Australia, Korea and Thailand switch to positive skewness (joining Hong Kong and Japan which also positive in non crisis times). The skewness coefficients for these countries are the set that are also positive during the Russian crisis. The LTCM and Brazilian crises which are in close proximity in time exhibit the biggest change with all apart from Canada and Germany being positive during the LTCM crisis in contrast to the Russian case in which it is nested. For Argentina, the regional countries of Brazil, Canada and the US all switched to positive skewness. In the global financial crisis it is mainly the developed countries returns which show positive skewness.

Examination of the statistics of dependence in Table 5 calculated using the non crisis data show that the most highly correlated markets are mainly regional. Argentina, Brazil, Canada and the US are most correlated with each other with coefficients ranging from 0.34 for Argentina and Canada to 0.51 for Canada and the US. Correlation amongst the Asian countries of Australia, Japan, Korea and Thailand are of similar magnitude.

The two versions of the coskewness statistics also allude to some interesting stories. The $\widehat{\psi}_x\left(r_i^1, r_j^2\right)$ statistic where each of the (later crisis) markets i are expressed in the level of the returns, and each market j in terms of volatility are generally negative. The exception is for the case where the US is country i. In this case the coskewness coefficients are positive. When the coskewness coefficient is reversed where it is the volatility in the US and the level of the other markets in the system $\widehat{\psi}_x\left(r_i^2, r_j^1\right)$, all coefficients are negative, and are much lower in value than in the $\widehat{\psi}_x\left(r_i^1, r_j^2\right)$ case. The lowest coefficient of coskewness is with Australia at -0.52. Volatility in the US appears to correspond with falls in the level of the other markets in a manner that is consistent with diversification choices in a portfolio where the US is considered equivalent to a less-risky asset, and where volatility in the less risky asset is tolerated at the expense of lower returns in other parts of the portfolio. The coskewness statistics also reflect some regional dependence with large absolute magnitudes of the coskewness coefficients, although this is only true for the Americas, and not Asia. In the crisis periods in Table 6 there is evidence that the correlation coefficients rise substantially, and that

Table 4:
Descriptive statistics for the non crisis data.

	Mean	Minimum	Maximum	Std Dev	Skewness
Argentina	0.04	-14.81	9.18	1.90	-0.39
Australia	0.05	-7.01	6.38	1.02	-0.37
Brazil	0.12	-16.42	9.85	2.11	-0.36
Canada	0.05	-8.93	4.40	1.00	-0.97
Germany	0.06	-5.79	4.49	0.96	-0.55
Hong Kong	0.05	-14.71	17.27	1.46	0.22
Japan	0.01	-6.14	6.70	1.41	0.04
Korea	0.03	-9.95	9.70	1.83	-0.10
Russia	0.11	-21.10	15.55	2.73	-0.47
Thailand	-0.03	-16.06	10.80	1.78	-0.35
UK	0.04	-4.87	5.57	0.96	-0.11
US	0.03	-7.45	4.60	0.93	-0.57

the coskewness statistics also appear to change in magnitude and sign. However, it is difficult to analyze these statistics during this period given the increases in volatility in the crisis period that complicates the calculation of these statistics as is well documented, so no comment is made on these preliminary statistics here apart from noting this change.

The empirical results for the correlation and coskewness tests for contagion are contained in Tables 7 to 10. Inspection of these tables shows that the global financial crisis is truly different to all other crises of the past two decades. Inspection of the first panel of Table 10 shows that clearly, all channels of contagion are operating compared to the other historical crises, and almost all countries are affected by more than one channel. The dependence structures based on the heteroskedasticity adjusted correlation coefficients change dramatically with evidence of contagion through this channel from the US equity market to all except for Canada, Japan and the UK. Similarly, in almost all cases, contagion also transmits through the coskewness channels, as the dependence between the volatility and mean structures of each asset market also changes significantly during the crisis. Only Australia through the $CS_1\left(i \rightarrow j; r_i^1, r_j^2\right)$ channel where Australian returns enter the coskewness calculations as the volatility term and Brazil and Germany through both coskewness channels do not change in this period.

Evidence on the hypothesis that crises beginning in the major financial centre of the

Table 5:
Correlation and coskewness coefficients with the crisis countries for the non crisis period.

	Argentina	Brazil	Hong Kong	Russia	US
			Correlations (ρ_x)		
Argentina	1.00	0.49	0.12	0.17	0.36
Australia	0.14	0.20	0.45	0.20	0.11
Brazil	0.49	1.00	0.17	0.20	0.44
Canada	0.34	0.42	0.21	0.22	0.51
Germany	0.20	0.28	0.28	0.25	0.23
Hong Kong	0.12	0.17	1.00	0.30	0.09
Japan	0.09	0.15	0.40	0.14	0.05
Korea	0.11	0.15	0.42	0.18	0.10
Russia	0.17	0.20	0.30	1.00	0.13
Thailand	0.13	0.15	0.33	0.19	0.05
UK	0.24	0.33	0.29	0.25	0.36
US	0.36	0.44	0.09	0.13	1.00
			Coskewness 1 $\widehat{\psi}_x\left(r_i^1, r_j^2\right)$		
Argentina	-0.39	-0.38	-0.20	-0.15	-0.28
Australia	-0.11	-0.13	-0.13	-0.20	-0.17
Brazil	-0.41	-0.36	-0.21	-0.18	-0.24
Canada	-0.49	-0.44	-0.14	-0.22	-0.38
Germany	-0.11	-0.23	-0.32	-0.28	-0.13
Hong Kong	-0.05	-0.18	0.22	-0.09	0.20
Japan	-0.05	-0.04	-0.05	-0.11	-0.07
Korea	-0.05	-0.11	-0.18	-0.17	-0.06
Russia	-0.09	-0.03	-0.31	-0.47	0.04
Thailand	0.12	0.06	0.00	-0.06	0.09
UK	-0.06	-0.08	-0.17	-0.08	0.00
US	-0.30	-0.14	-0.39	-0.23	-0.57
			Coskewness 2 $\widehat{\psi}_x\left(r_i^2, r_j^1\right)$		
Argentina	-0.39	-0.41	-0.05	-0.09	-0.30
Australia	-0.14	-0.27	-0.07	-0.29	-0.52
Brazil	-0.38	-0.36	-0.18	-0.03	-0.14
Canada	-0.32	-0.30	0.12	-0.07	-0.32
Germany	-0.13	-0.30	-0.18	-0.27	-0.27
Hong Kong	-0.20	-0.21	0.22	-0.31	-0.39
Japan	-0.07	-0.13	-0.09	-0.16	-0.22
Korea	-0.27	-0.24	-0.20	-0.27	-0.33
Russia	-0.15	-0.18	-0.09	-0.47	-0.23
Thailand	0.03	-0.07	-0.36	-0.27	-0.22
UK	-0.14	-0.17	-0.01	-0.08	0.03
US	-0.28	-0.24	0.20	0.04	-0.57

Table 6:
Crisis period descriptive statistics for the crisis periods.

		Mean	Min	Max	Std Dev	Skew	Correl. ρ_y	Coskew 1 $\widehat{\psi}_y\left(r_i^1, r_j^2\right)$	Coskew 2 $\widehat{\psi}_y\left(r_i^2, r_j^1\right)$
Asia	Argentina	-0.03	-6.13	4.80	2.03	-0.56	0.46	0.02	0.44
	Australia	0.01	-3.13	3.58	1.25	0.13	0.54	0.00	-0.05
	Brazil	0.07	-10.89	7.81	2.56	-0.86	0.36	-0.36	0.21
	Canada	0.02	-2.80	1.71	0.94	-0.58	0.50	-0.13	0.11
	Germany	0.09	-2.20	2.07	0.90	-0.16	0.35	-0.31	-0.05
	Hong Kong	-0.12	-9.07	13.41	2.80	0.75	1.00	0.75	0.75
	Japan	-0.19	-6.67	8.69	2.51	0.33	0.41	0.15	0.13
	Korea	-0.24	-15.47	20.43	5.88	0.28	0.16	-0.13	0.27
	Russia	-0.50	-15.49	6.89	3.81	-0.81	0.48	-0.50	-0.04
	Thailand	-0.34	-14.07	14.82	4.25	0.87	0.50	0.38	0.63
	UK	0.10	-2.44	2.62	1.03	-0.04	0.44	0.15	0.51
	US	0.09	-2.89	2.51	0.91	-0.20	0.43	0.05	0.51
Russia	Argentina	-0.20	-14.30	8.43	3.80	-0.63	0.35	-0.24	-0.45
	Australia	0.11	-5.00	7.37	1.58	0.85	0.33	-0.40	-0.44
	Brazil	-0.44	-17.23	12.61	4.71	-0.24	0.24	-0.10	-0.36
	Canada	0.03	-7.49	4.60	1.77	-0.87	0.46	-0.83	-0.62
	Germany	-0.01	-3.69	3.18	1.33	-0.31	0.48	-0.27	-0.39
	Hong Kong	0.39	-7.34	8.61	2.55	0.33	0.14	-0.20	0.08
	Japan	0.19	-4.64	12.57	2.53	1.28	0.16	0.30	-0.07
	Korea	0.85	-6.15	11.01	3.19	0.69	0.16	0.28	-0.03
	Russia	-0.63	-18.78	12.38	4.92	-0.63	1.00	-0.63	-0.63
	Thailand	0.52	-8.22	9.64	3.22	0.25	0.03	0.09	0.06
	UK	0.13	-3.53	3.75	1.52	-0.10	0.36	-0.30	-0.40
	US	0.11	-6.58	4.86	1.68	-0.56	0.28	-0.23	-0.33
LTCM	Argentina	1.74	-4.42	7.91	3.88	0.14	0.91	0.13	0.09
	Australia	0.54	-2.06	7.37	2.43	1.43	-0.08	-0.34	-0.23
	Brazil	1.09	-6.13	10.42	4.57	0.44	0.85	0.31	0.17
	Canada	0.40	-4.12	4.60	2.29	-0.05	0.71	-0.01	0.13
	Germany	0.00	-3.69	3.18	1.86	-0.47	0.25	0.38	0.18
	Hong Kong	1.70	-1.89	6.90	2.56	0.40	0.17	0.11	0.05
	Japan	0.64	-4.61	12.57	4.08	1.54	0.11	-0.52	-0.33
	Korea	2.03	-2.33	8.88	3.60	0.75	0.26	0.28	0.19
	Russia	1.24	-5.93	12.38	5.33	0.50	0.26	0.55	0.09
	Thailand	2.48	-2.00	9.64	3.51	0.70	0.02	-0.68	0.04
	UK	0.17	-2.90	3.12	1.61	0.07	0.37	0.38	-0.12
	US	0.59	-2.99	4.06	1.82	0.02	1.00	0.02	0.02

Table 6 continued.

		Mean	Min	Max	Std Dev	Skew	Correl. ρ_y	Coskew 1 $\widehat{\psi}_y\left(r_i^1, r_j^2\right)$	Coskew 2 $\widehat{\psi}_y\left(r_i^2, r_j^1\right)$
Brazil	Argentina	-0.32	-10.80	11.64	3.70	0.29	0.89	0.42	0.53
	Australia	0.01	-2.54	1.83	1.04	-0.43	0.45	-0.24	-0.06
	Brazil	-0.93	-13.75	18.02	6.52	0.65	1.00	0.65	0.65
	Canada	-0.24	-2.61	2.46	1.26	0.16	0.42	0.22	0.37
	Germany	-0.23	-1.93	1.35	0.85	-0.14	-0.32	0.24	-0.66
	Hong Kong	-0.45	-4.15	2.99	1.83	-0.10	0.25	-0.35	-0.24
	Japan	0.11	-2.30	2.76	1.36	0.08	-0.06	-0.47	0.11
	Korea	-0.97	-5.65	7.00	2.76	0.84	0.28	-0.06	0.15
	Russia	0.43	-7.83	7.12	3.36	0.00	0.18	-0.32	-0.60
	Thailand	-0.69	-5.33	10.41	2.73	2.05	0.16	-0.18	-0.20
	UK	-0.23	-2.57	1.81	1.15	0.23	0.55	0.36	0.52
	US	-0.05	-2.48	2.38	1.22	0.16	0.45	0.11	0.16
Dotcom	Argentina	-0.40	-6.57	5.92	2.28	-0.08	0.54	-0.36	-0.51
	Australia	-0.09	-6.77	3.00	1.42	-1.38	0.00	0.61	0.04
	Brazil	-0.17	-5.65	5.70	2.66	0.28	0.51	0.08	-0.26
	Canada	-0.04	-6.35	3.66	1.95	-0.35	0.53	-0.49	-0.56
	Germany	0.04	-2.56	2.05	1.15	-0.16	0.12	0.21	0.00
	Hong Kong	-0.15	-8.94	5.04	2.38	-0.51	-0.11	0.33	-0.35
	Japan	-0.06	-6.65	3.12	1.53	-1.11	-0.15	0.36	0.02
	Korea	-0.17	-12.41	7.64	3.42	-0.47	0.05	0.27	-0.37
	Russia	0.01	-8.16	6.82	3.58	-0.31	0.00	-0.03	-0.01
	Thailand	-0.14	-5.36	5.68	2.43	0.07	-0.06	0.30	-0.06
	UK	-0.09	-3.08	3.35	1.45	0.03	0.36	-0.06	-0.40
	US	0.16	-5.82	4.81	1.70	-0.40	1.00	-0.40	-0.40
Argentina	Argentina	-0.02	-19.95	16.12	3.72	-0.20	1.00	-0.20	-0.20
	Australia	0.00	-3.79	3.88	1.02	-0.01	0.08	-0.03	-0.17
	Brazil	-0.09	-8.09	12.73	3.04	0.39	0.12	0.08	-0.18
	Canada	-0.02	-3.75	3.91	1.12	0.21	0.16	-0.12	-0.34
	Germany	-0.07	-3.94	3.72	1.05	-0.09	0.13	-0.06	-0.13
	Hong Kong	-0.06	-3.77	4.22	1.26	0.30	0.11	-0.02	0.08
	Japan	0.00	-5.31	6.61	1.76	0.16	0.13	-0.05	0.03
	Korea	0.08	-7.48	7.36	2.06	-0.24	0.17	-0.10	0.11
	Russia	0.08	-7.68	5.49	2.01	-0.11	0.13	-0.06	-0.16
	Thailand	0.05	-4.26	4.33	1.39	-0.12	-0.02	-0.03	0.04
	UK	-0.11	-5.31	5.14	1.61	-0.08	0.12	0.01	-0.15
	US	-0.04	-4.75	6.15	1.59	0.42	0.14	-0.04	-0.23

Table 6 continued.

		Mean	Min	Max	Std Dev	Skew	Correl. ρ_y	Coskew 1 $\widehat{\psi}_y\left(r_i^1, r_j^2\right)$	Coskew 2 $\widehat{\psi}_y\left(r_i^2, r_j^1\right)$
GFC	Argentina	-0.02	-12.86	10.88	2.31	-0.66	0.58	-0.59	-0.49
Total	Australia	-0.03	-16.00	8.51	2.52	-0.82	0.22	-0.08	-0.06
	Brazil	0.04	-17.96	16.86	3.24	-0.27	0.67	-0.05	-0.02
	Canada	-0.01	-13.79	9.93	2.31	-0.66	0.67	-0.57	-0.37
	Germany	-0.04	-11.33	11.89	2.38	0.00	0.50	-0.07	-0.18
	Hong Kong	-0.01	-13.59	13.40	2.43	0.15	0.26	0.34	0.37
	Japan	-0.03	-11.19	11.64	1.99	-0.20	-0.01	0.08	-0.12
	Korea	-0.05	-14.69	15.70	2.35	-0.20	0.20	0.10	0.02
	Russia	-0.03	-21.20	20.20	3.09	-0.27	0.29	-0.25	-0.26
	Thailand	-0.01	-11.60	7.85	1.79	-0.64	0.27	-0.25	-0.07
	UK	-0.06	-10.54	12.22	2.21	0.00	0.52	-0.13	-0.22
	US	-0.03	-8.20	10.51	1.75	0.09	1.00	0.09	0.09
GFC	Argentina	-0.28	-12.86	10.88	2.78	-0.65	0.56	-0.65	-0.48
Regime 1	Australia	-0.26	-12.61	8.51	3.19	-0.45	0.19	0.02	-0.01
	Brazil	-0.26	-17.96	16.86	4.23	-0.06	0.66	0.09	0.09
	Canada	-0.19	-13.79	9.93	2.80	-0.38	0.69	-0.54	-0.34
	Germany	-0.29	-11.33	11.89	2.76	0.21	0.49	0.04	-0.10
	Hong Kong	-0.14	-9.01	13.40	3.04	0.62	0.27	0.56	0.41
	Japan	-0.17	-11.19	11.64	2.43	-0.06	-0.02	0.18	-0.11
	Korea	-0.31	-15.42	15.42	3.26	-0.08	0.21	0.15	0.06
	Russia	-0.45	-21.20	20.20	3.86	-0.21	0.27	-0.25	-0.27
	Thailand	-0.12	-7.39	7.85	1.99	0.04	0.32	-0.16	-0.02
	UK	-0.34	-10.49	12.22	2.75	0.35	0.51	-0.03	-0.15
	US	-0.21	-8.20	10.51	2.28	0.22	1.00	0.22	0.22
GFC	Argentina	0.48	-6.22	6.66	1.95	-0.18	0.66	-0.04	0.19
Regime 2	Australia	0.44	-4.04	5.96	1.89	0.10	0.38	0.03	0.19
	Brazil	0.50	-6.98	8.14	2.28	-0.24	0.74	-0.06	0.21
	Canada	0.45	-6.28	5.62	1.85	-0.40	0.76	-0.15	0.25
	Germany	0.46	-6.87	7.36	2.12	-0.17	0.61	-0.17	-0.02
	Hong Kong	0.26	-4.97	7.16	1.85	0.26	0.32	0.19	0.46
	Japan	0.17	-3.50	5.11	1.53	0.11	0.02	-0.05	0.06
	Korea	0.32	-4.45	5.53	1.77	-0.10	0.28	0.34	0.42
	Russia	0.58	-5.45	9.67	2.54	0.19	0.54	0.17	0.31
	Thailand	0.26	-5.73	5.75	1.67	-0.27	0.24	-0.01	0.11
	UK	0.31	-4.49	6.64	1.72	0.20	0.61	0.01	0.15
	US	0.26	-3.63	6.61	1.30	0.68	1.00	0.68	0.68

US have important consequences for the rest of world is not supported by examining the first panel in each of Tables 8 and 9. These tables contain the test statistics relating to the LTCM and dotcom crises, the other US sourced crises. In fact, the LTCM crisis barely shows any evidence of contagion.[3] The only channel operating is to the regional countries of Argentina and Brazil through the correlation channel, and it was only less than three months later that Brazil experienced its own crisis, suggesting already its vulnerability. The dotcom crisis affects mainly the developed countries in the sample through the correlation channel, with the exception of Australia who had little of its own tech related industry, perhaps explaining this exception. Australia, Canada and the UK were the only countries affected by the $CS_2\left(i \to j; r_i^2, r_j^1\right)$ channel where the US represents the volatility term in this version of the statistic. There are no cases of contagion through the $CS_1\left(i \to j; r_i^1, r_j^2\right)$ channel. The result where there is little contagion from the US implies that the spillovers of the LTCM and dotcom crises to the other countries in the sample are well accounted for by normal interdependencies, and that transmission channels of shocks across countries have not changed for most countries during these crises. This is possibly an effect of the US being a large and efficient market, where linkages across markets are well understood and with any arbitrage opportunities well exploited. This reiterates that the global financial crisis is truly a different crisis - perhaps as it was revealed that linkages across markets are not as well understood as previously thought.

Just over half of the set of crises in the sample are sourced in emerging markets including Hong Kong, Russia, Brazil and Argentina. The pattern is similar across most of these emerging market sourced crises, particularly for Asia, Russia and Brazil. In these cases, about two thirds of the countries are affected through one channel only, with no channel dominating. The evidence falls fairly evenly across the three channels, with 12 of the 99 possible channels in these three crises being correlation based, 9 being $CS_1\left(i \to j; r_i^1, r_j^2\right)$ based, and 10 being $CS_2\left(i \to j; r_i^2, r_j^1\right)$ based, reiterating the result in Fry, Martin and Tang (2010) that more than just the correlation based channel should be considered when evaluating the existence of contagion.

Leaving aside the Brazilian crisis, the pattern appears to be that countries with strong regional linkages are affected through direct correlation measures. In fact it appears that countries less likely to have linkages with a particular country are more likely to show contagion through the higher order channels, perhaps alluding to port-

[3] Note the use of the finite sample critical values determined in Section 3.3

folio allocation behavior, rather than direct financial market linkages. For example, in Asia, the correlation based channel is active for the Asian countries of Japan, Korea and Thailand, with only the UK being affected by this channel not in the region. Argentina, Brazil, Canada and the US who are presumably less connected to Asia through trade and other financial market linkages are affected through $CS_1\left(i \to j; r_i^1, r_j^2\right)$ or $CS_2\left(i \to j; r_i^2, r_j^1\right)$. Germany and Hong Kong are also affected by Russia as measured by the correlation based measure. That Germany is affected is consistent with previous work on the Russian crisis showing that Germany was affected by contagion, potentially reflecting the banking linkages of Germany with Russian banks (see Van Rijckeghem and Weder, 2003 and Dungey et al., 2007). The result of contagion from Russia to Hong Kong may reflect that the Hong Kong Monetary Authority intervened in the Hong Kong equity market to support the currency board in August of 1998 (Goodhart and Dai, 2003). Countries less likely to have direct linkages with Russia are affected through the higher order terms including Australia, Canada, Japan and Korea.

The results that the crisis in Argentina appears to show substantial evidence of contagion is at first pass unexpected. The correlation channel affects all markets except for Japan and Korea, and there is also evidence that there is $CS_1\left(i \to j; r_i^1, r_j^2\right)$ contagion to Brazil, Canada, Germany and the US, and $CS_2\left(i \to j; r_i^2, r_j^1\right)$ contagion to Hong Kong and Russia. This result may be driven by the fundamental change in Argentina during this crisis period rather than contagion. The collapse of the currency board in January 2002 changed the relationship with the US and Argentina through the change in the currency arrangements, and hence is reflected in most of the other markets in the sample as well. This is not necessarily evidence of contagion, but will be reflected as contagion in these statistics, as even in a non crisis period, the relationship between Argentina and the other markets change permanently.

As the duration of the global financial crisis is quite long, the current crisis is divided into two regimes to determine how the dynamics change over the crisis. The two regimes are fairly similar, with all channels operating. There are more instances of correlation based contagion in the second regime than in the first regime. There is also a clear reduction in the number of countries affected by contagion through higher order channels in the second regime. Argentina, Brazil, Canada, Germany, Japan and the UK are no longer affected by contagion through higher order channels. It can be hypothesized that in the worst of a crisis, the higher order contagious channels are most active as investors reassess risk. It seems that these risk quantities and hence the coskewness based tests are critical to consider. In particular, is seems that the $CS_1\left(i \rightarrow j; r_i^1, r_j^2\right)$ channel is more active in the first regime of the crisis.

5 Conclusions

This paper examined the transmission of contagion across equity markets in seven financial crises using tests for contagion developed by Fry, Martin and Tang (2010). The contagion tests were defined as significant changes in the comoments of the distribution of equity returns in a crisis period in comparison to a non crisis period. The comoments considered were correlation and two forms of coskewness. A significant change in these distributions provided evidence of contagion.

The crises considered were the Asian financial crisis, the 1998 Russian debt default, the 1998 near-collapse of LTCM, the Brazilian crisis in 1999, the 2000 dotcom crisis, the Argentinean crisis of 2001 to 2002 and the global financial crisis of 2007-2010. The results showed that the global financial crisis was truly different to any of the other crises of the past two decades with all transmission channels operating. However, it was not the case that the other US sourced crises were as systemic as the global financial crisis. In fact, in some US based crises there was virtually no evidence of contagion. It is possible that the well developed nature of the US market means that crises transmit through normal inter linkages rather than through new or altered channels. Again, this reiterates that the most recent crisis truly is different than those that have gone before.

The emerging market crises in the sample with the exception of Argentina revealed that about two thirds of countries in the sample were affected by one channel of contagion during these crises, although the channels through which contagion transmitted were equally active. This implies that more than just the correlation based channel should be examined during when analyzing crises. It also appeared that the markets expected not to have linkages with the source country were more likely to be affected through the higher order channels. Finally, the high incidence of contagion to developed markets in the Argentinean crisis probably reflected the fundamental structural change which occurred in Argentina with the abolishment of the currency board in 2002.

Table 7:
Contagion during the i) Asian crisis from the Hong Kong equity market (i) and during the ii) Russian crisis from the Russian equity market (i). CR is the correlation based contagion test in (11); The coskewness contagion test $CS_1\left(i \to j; r_i^1, r_j^2\right)$ measures coskewness in terms of the source market returns i and squared returns of markets j and is based on equation (19). The coskewness contagion test $CS_2\left(i \to j; r_i^2, r_j^1\right)$ measures coskewness in terms of the squared source market returns i and returns of markets j and is based on equation (20).

		CR	p-values	CS_1	p-values	CS_2	p-values
Asia	Argentina	1.55	0.21	6.84	0.01	1.28	0.26
	Australia	0.78	0.38	3.18	0.07	1.84	0.18
	Brazil	3.10	0.08	5.00	0.03	0.09	0.77
	Canada	0.65	0.42	3.37	0.07	11.69	0.00
	Germany	0.62	0.43	0.26	0.61	0.00	0.95
	Japan	35.89	0.00	0.94	0.33	4.46	0.03
	Korea	68.11	0.00	1.07	0.30	5.27	0.02
	Russia	0.14	0.71	1.49	0.22	1.82	0.18
	Thailand	14.93	0.00	0.37	0.54	4.43	0.04
	UK	4.70	0.03	0.03	0.87	3.20	0.07
	US	0.13	0.72	9.72	0.00	3.52	0.06
Russia	Argentina	0.15	0.69	0.84	0.36	3.33	0.07
	Australia	2.11	0.15	0.03	0.86	3.74	0.05
	Brazil	0.87	0.35	0.09	0.76	3.38	0.07
	Canada	1.74	0.19	11.04	0.00	6.35	0.01
	Germany	4.09	0.04	0.18	0.67	0.89	0.35
	Japan	5.18	0.02	0.51	0.47	2.61	0.11
	Korea	0.16	0.69	4.57	0.03	0.30	0.58
	Hong Kong	0.05	0.83	7.99	0.00	0.11	0.74
	Thailand	7.46	0.01	0.27	0.60	0.99	0.32
	UK	0.47	0.49	0.40	0.53	1.42	0.23
	US	0.02	0.88	1.12	0.29	1.96	0.16

Table 8:
Contagion during the i) LTCM crisis from the US equity market (i) and ii) during the Brazilian crisis from the Brazilian equity market (i). CR is the correlation based contagion test in (11); The coskewness contagion test $CS_1\left(i \rightarrow j; r_i^1, r_j^2\right)$ measures coskewness in terms of the source market returns i and squared returns of markets j and is based on equation (19). The coskewness contagion test $CS_2\left(i \rightarrow j; r_i^2, r_j^1\right)$ measures coskewness in terms of the squared source market returns i and returns of markets j and is based on equation (20).

		CR	p-values	CS_1	p-values	CS_2	p-values
LTCM	Argentina	32.98	0.00	0.05	0.83	0.08	0.77
	Australia	0.89	0.35	0.14	0.70	0.16	0.69
	Brazil	3.74	0.05	0.17	0.68	0.02	0.89
	Canada	0.00	0.96	0.47	0.49	0.31	0.58
	Germany	0.24	0.63	2.57	0.11	0.44	0.51
	Hong Kong	0.16	0.69	0.25	0.61	0.58	0.45
	Japan	0.05	0.83	0.95	0.33	1.04	0.31
	Korea	1.33	0.25	2.94	0.09	0.44	0.51
	Russia	0.36	0.55	1.91	0.17	0.03	0.86
	Thailand	0.10	0.75	0.98	0.32	0.09	0.77
	UK	1.70	0.19	0.00	0.95	0.23	0.63
Brazil	Argentina	0.46	0.50	9.95	0.00	11.94	0.00
	Australia	0.00	0.99	2.45	0.12	8.87	0.00
	Canada	15.93	0.00	12.02	0.00	11.64	0.00
	Germany	33.18	0.00	0.14	0.71	0.26	0.61
	Hong Kong	1.99	0.16	0.00	0.98	0.95	0.33
	Japan	4.86	0.03	3.40	0.07	6.98	0.01
	Korea	0.25	0.62	0.27	0.60	3.54	0.06
	Russia	4.75	0.03	1.20	0.27	1.32	0.25
	Thailand	3.28	0.07	0.09	0.76	0.00	0.97
	UK	2.41	0.12	9.11	0.00	14.81	0.00
	US	16.53	0.00	0.18	0.67	2.23	0.14

Table 9:
Contagion during the i) Dotcom crisis from the US equity market (i) and ii) during the Argentinean crisis from the Argentinean equity market (i). CR is the correlation based contagion test in (11); The coskewness contagion test $CS_1\left(i \rightarrow j; r_i^1, r_j^2\right)$ measures coskewness in terms of the source market returns i and squared returns of markets j and is based on equation (19). The coskewness contagion test $CS_2\left(i \rightarrow j; r_i^2, r_j^1\right)$ measures coskewness in terms of the squared source market returns i and returns of markets j and is based on equation (20).

		CR	p-values	CS_1	p-values	CS_2	p-values
Dotcom	Argentina	0.00	0.98	1.53	0.22	2.99	0.08
	Australia	1.25	0.26	0.09	0.77	7.97	0.00
	Brazil	2.46	0.12	0.41	0.52	1.37	0.24
	Canada	7.97	0.00	1.10	0.29	4.89	0.03
	Germany	10.63	0.00	1.66	0.20	1.97	0.16
	Hong Kong	4.39	0.04	1.53	0.22	0.83	0.36
	Japan	4.21	0.04	0.39	0.53	1.69	0.19
	Korea	0.32	0.57	1.96	0.16	1.31	0.25
	Russia	4.25	0.04	0.10	0.75	0.59	0.44
	Thailand	0.94	0.33	0.83	0.36	0.86	0.35
	UK	8.17	0.00	0.52	0.47	3.83	0.05
Argentina	Australia	15.81	0.00	1.02	0.31	0.75	0.39
	Brazil	213.55	0.00	11.60	0.00	0.16	0.68
	Canada	81.68	0.00	11.51	0.00	0.17	0.68
	Germany	29.48	0.00	5.21	0.02	0.29	0.59
	Hong Kong	17.85	0.00	0.33	0.56	24.04	0.00
	Japan	2.20	0.14	0.09	0.76	2.38	0.12
	Korea	1.02	0.31	0.10	0.75	3.33	0.07
	Russia	14.69	0.00	1.34	0.25	4.47	0.03
	Thailand	22.11	0.00	0.08	0.78	1.73	0.19
	UK	39.67	0.00	4.35	0.04	2.10	0.15
	US	83.44	0.00	2.04	0.15	0.26	0.61

Table 10:
Contagion during the global financial crisis from the US equity market (i) in the i) total period - July 26, 2007 to April 27, 2010; ii) regime 1 - July 26, 2007 to March 9, 2009; and iii) regime 2 - March 10, 2009 to April 27, 2010. CR is the correlation based contagion test in (11); The coskewness contagion test $CS_1\left(i \rightarrow j; r_i^1, r_j^2\right)$ measures coskewness in terms of the source market returns i and squared returns of markets j and is based on equation (19). The coskewness contagion test $CS_2\left(i \rightarrow j; r_i^2, r_j^1\right)$ measures coskewness in terms of the squared source market returns i and returns of markets j and is based on equation (20).

		CR	p-values	CS_1	p-values	CS_2	p-values
Total	Argentina	4.36	0.04	55.44	0.00	22.34	0.00
	Australia	21.23	0.00	1.04	0.31	26.06	0.00
	Brazil	5.20	0.02	0.02	0.89	0.43	0.51
	Canada	1.05	0.31	18.91	0.00	9.97	0.00
	Germany	16.91	0.00	1.31	0.25	0.00	0.96
	Hong Kong	12.99	0.00	65.35	0.00	101.92	0.00
	Japan	0.03	0.86	13.01	0.00	8.78	0.00
	Korea	9.52	0.00	40.31	0.00	28.29	0.00
	Russia	7.43	0.01	9.11	0.00	5.79	0.02
	Thailand	21.29	0.00	4.59	0.03	7.64	0.01
	UK	0.60	0.44	7.05	0.01	15.42	0.00
Regime 1	Argentina	0.08	0.77	44.04	0.00	15.57	0.00
	Australia	9.37	0.00	1.05	0.30	20.27	0.00
	Brazil	0.10	0.76	0.72	0.40	0.04	0.84
	Canada	11.36	0.00	11.64	0.00	5.80	0.02
	Germany	4.12	0.04	2.63	0.10	0.52	0.47
	Hong Kong	6.12	0.01	54.62	0.00	72.71	0.00
	Japan	0.02	0.89	13.97	0.00	7.81	0.01
	Korea	4.65	0.03	31.24	0.00	20.77	0.00
	Russia	0.69	0.41	9.63	0.00	5.46	0.02
	Thailand	16.17	0.00	2.19	0.14	9.22	0.00
	UK	1.28	0.26	3.12	0.08	7.27	0.01
Regime 2	Argentina	48.57	0.00	1.92	0.17	10.58	0.00
	Australia	31.27	0.00	18.16	0.00	34.28	0.00
	Brazil	57.99	0.00	1.62	0.20	4.90	0.03
	Canada	26.16	0.00	2.35	0.13	11.32	0.00
	Germany	50.65	0.00	1.04	0.31	3.46	0.06
	Hong Kong	14.62	0.00	10.84	0.00	46.49	0.00
	Japan	0.70	0.40	1.20	0.27	3.87	0.05
	Korea	8.34	0.00	32.79	0.00	32.48	0.00
	Russia	42.55	0.00	9.91	0.00	14.28	0.00
	Thailand	7.63	0.01	0.00	0.98	7.01	0.01
	UK	18.16	0.00	1.96	0.16	1.59	0.21

References

[1] Baig, T., and Goldfajn, I. (1999), "Financial Market Contagion in the Asian Crisis," IMF Staff Papers, 46, 167-195.

[2] 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.

[3] Baur, D., and Fry R.A. (2009), "Multivariate Contagion and Interdependence," *Journal of Asian Economics*, 20, 353-366.

[4] Boschi, M. (2005), "International Financial Contagion: Evidence From the Argentine Crisis of 2001-2002", *Applied Financial Economics*, 15, 153-163.

[5] Caporale, G.M., Cipollini, A. and Spagnolo, N. (2005), "Testing for Contagion: A Conditional Correlation Analysis," *Journal of Empirical Finance*, 12, 476-89.

[6] Campbell, J.Y., Lo, A.W., and MacKinlay, A.C. (1997), *The Econometrics of Financial Markets*, Princeton University Press, Princeton, New Jersey.

[7] Caprio, G., Klingebiel, D., Laeven, L., and Noguera, G. (2005), "Appendix: Banking Crisis Database," in Patrick Honohan and Luc Laeven (eds.), *Systemic Financial Crises: Containment and Resolution*, Cambridge, U.K.: Cambridge University Press.

[8] Cifarelli, G. and Paladino G. (2004), "The Impact of the Argentine Default on Volatility Co-movements in Emerging Bond Markets," *Emerging Markets Review*, 5, 427-446.

[9] Cobb, L., Koppstein, P., and Chen, N.H. (1983), "Estimation and Moment Recursion Relations for Multimodal Distributions of the Exponential Family," *Journal of the American Statistical Association*, 78, 124-130.

[10] Corsetti, G. and Pesenti, P. (2005), "The Simple Geometry of Transmission and Stabilization in Closed and Open Economies," *NBER Working Paper*, No. 11341.

[11] Craine, R. and Martin, V.L. (2008), "International Monetary Policy Surprise Spillovers", *Journal of International Economics,* 75, 180-196.

[12] Committee on the Global Financial System (1999), "Bank for International Settlements. A Review of Financial Market Events in Autumn 1998," Basel, Switzerland, October.

[13] Dornbusch, R., Park, Y.C., and Claessens, S. (2000),"Contagion: Understanding How It Spreads," *The World Bank Research Observer*, 15, 177-197.

[14] Dungey, M., Fry, R.A., González-Hermosillo, B. and Martin, V.L. (2006), "Contagion in International Bond Markets During the Russian and LTCM Crises", *Journal of Financial Stability*, 2, 1–27.

[15] Dungey, M., Fry, R.A., González-Hermosillo, B. and Martin, V.L. (2005), "A Review of Methodologies," *Quantitative Finance*, 5, 9-24.

[16] Dungey, M., Fry, R.A., González-Hermosillo, B., Martin, V.L., and Tang, C. (2009), "Are Financial Crises Alike?," IMF Working Paper #WP/10/14..

[17] Dungey, M., Fry, R.A., González-Hermosillo, B., Martin, V.L. (2007), "Contagion in Global Equity Markets in 1998: The Effects of the Russian and LTCM Crises", *The North American Journal of Economics and Finance*, 18, 155-174.

[18] Dungey, M., Fry, R.A., Martin, V.L. (2006), "Correlation, Contagion and Asian Evidence," Asian Economic Papers, 5, 32-37.

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

[20] Fry, R.A., Martin, V.L., Tang, C. (2010), "A New Class of Tests of Contagion with Applications", *Journal of Business and Economic Statistics*, 28, 423–437.

[21] Goodhart C. and Dai L. (2003), "Intervention to Save Hong Kong: Counter-Speculation In Financial Markets," Oxford University Press: Oxford.

[22] Guidolin, M. and Timmerman, A. (2009), "International Asset Allocation Under Regime Switching, Skew and Kurtosis Preferences", *Review of Financial Studies,* 21, 889-935.

[23] Harvey, C.R., and Siddique, A. (2000), "Conditional Skewness in Asset Pricing Tests," *Journal of Finance*, 55, 1263-1295.

[24] Ingersoll, J. (1990), *Theory of Financial Decision Making*, Rowman and Littlefield, Totowa, New Jersey.

[25] International Monetary Fund (2003), Lessons from the Crisis in Argentina, Policy Development and Review Department, Washington D.C.

[26] Kaminsky, G.L. and Reinhart, C.M. (2003), "The Center and the Periphery: The Globalization of Financial Turmoil," NBER Working Paper #9479.

[27] Kharas, H., B. Pinto and S. Ulatov (2001), "An Analysis of Russia's 1998 Meltdown: Fundamentals and Market Signals," Brookings Papers on Economic Activity, Brookings Institution, 1 pp.1-68

[28] King, M. and Wadhwani, S. (1990), "Transmission of Volatility Between Stock Market," *Review of Financial Studies*, 3,5-33.

[29] Knight, J. Lizieri, C., and Satchell, S. (2005),"Diversification when It Hurts? The Joint Distributions of Real Estate and Equity Markets," *Journal of Property Research*, 22, 309-323.

[30] Laeven, L. and Valencia, F. (2008), "Systemic Banking Crises: A New Database," *IMF Working Paper*, WP/08/224.

[31] Lye, J.N., and Martin, V.L. (1993), "Robust Estimation, Non-Normalities and Generalized Exponential Distributions," *Journal of the American Statistical Association*, 88, 253-259.

[32] Reinhart, C. (2010), "This Time is Different Chartbook: Country Histories on Debt, Default, and Financial Crises,", *NBER Working Paper*, #15815.

[33] Reinhart, C. and Rogoff, K.S. (2008), "Is the 2007 US Sub-Prime Financial Crisis So Different? An International Historical Comparison," *NBER Working Paper* #13761.

[34] Rigobon, R. (2003), "On the Measurement of the International Propagation of Shocks: Is the Transmission Stable?," *Journal of International Economics*, 61, 261-283.

[35] Pericoli, M., and Sbracia, M. (2003), "A Primer on Financial Contagion," *Journal of Economic Surveys*, 17, 571-608.

[36] Van Rijckeghem, C. and Weder, B. (2003), "Spillovers Through Banking Centers: A Panel Data Analysis of Bank Flows," *Journal of International Money and Finance*, 22, 483-509.

[37] Walti, S. and Weder, G. (2008), "Recovering from Bond Market Distress: Good Luck and Good Policy," *Emerging Markets Review*, 10, 36-50.

[38] Wongswan, Jon. (2003), "Contagion: An Empirical Test," International Finance Discussion Paper no. 775. Washington, D.C.: Board of Governors of the Federal Reserve System.

[39] Yuan, K. (2005), "Asymmetric Price Movements and Borrowing Constraints: A Rational Expectations Equilibrium Model of Crises, Contagion and Confusion," *Journal of Finance*, LX, 379-411.