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Extreme Contagion in Equity Markets

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Extreme Contagion in Equity Markets

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Abstract

This study uses bivariate extremal dependence measures, based on the number of equity return co-exceedances in two markets, to quantify both negative and positive equity returns contagion in mature and emerging equity markets during the past decade. The results indicate (a) higher contagion for negative returns than for positive returns; (b) a secular increase in contagion in Latin America not matched in other regions; (c) global increases in contagion following the 1998 financial crises; and (d) that the use of simple correlations as a proxy for contagion could be misleading, as the former exhibit low correlation with extremal dependence measures of contagion.

JEL Classification Numbers: F30, G10, G15, C10

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I. Introduction

It has been widely documented that the comovement of prices in financial markets increases significantly during periods of stress, such as the Exchange Rate Mechanism crisis in 1992-93, the Mexican crisis in 1994, and the more recent financial crises in East Asia in 1997, and in Russia and Brazil in 1998.[2] Both policy makers and academics have interpreted upward changes in price comovements or correlations as evidence of a breakdown of current transmission mechanisms across financial markets or contagion. However, sudden correlation changes are not necessary nor sufficient conditions to identify contagion or crisis periods, as they do not necessarily imply a structural change in the data generating process. For example, suppose that the data generating process for two series is a bivariate normal distribution with a constant correlation coefficient. A sample realization from this distribution can be divided into two subsamples, the first one comprising the 50 percent smallest returns and the second one 50 percent largest returns. The conditional correlation of the latter subsample would be higher than that corresponding to the first subsample. However, the data generating process remains unchanged.

An alternative statistical approach to studying contagion in financial markets is to use extreme value theory (EVT). EVT techniques can be used to quantify contagion as the joint behavior of extremal realizations (or co-exceedances) of financial prices or returns across different markets, where extremal realizations or exceedances are defined as those realizations exceeding a large threshold value. EVT measures of contagion, thus, can be referred to as *extreme* contagion measures. The EVT approach to contagion, which has gained acceptance in recent years, captures well the belief by most observers in the private and policy making communities that large shocks are transmitted across financial markets differently than small shocks.[3]

This paper uses the EVT approach to examine the evolution of extreme downside (bear market) and upside (bull market) contagion in equity markets returns in a number of mature markets and emerging markets using weekly data during the period December 31, 1987 to October 25, 2001. Contagion is estimated across pairwise combinations of equity markets using a five-year rolling window and assuming that negative (positive) extremal returns characterizing bear (bull) market periods are those lying in the bottom (top) 5 percent of the return distribution in each five-year rolling window.

[2] Increased price synchronicity is also experienced during bull markets, though to a lesser extent. See Chan-Lau and Ivaschenko for a recent analysis of the tech-bubble of the 1990s.

[3] Bae, Karolyi, and Stulz (2000), Longin and Solnik(2001), Hartmann, Straetmans, and de Vries (2001), Poon, Rockinger and Tawn (2001), Quintos (2001), and Starica (1999), among others are examples of recent empirical work that emphasizes this definition of contagion.

The extremal dependence measures used to gauge the extent of contagion are the ones first proposed by Coles, Heffernan, and Tawn (1999). This dependence measure embodies two dimensions of contagion. The first dimension is associated to the type of asymptotic tail property that govern the joint behavior of the realizations of two series in the limit. Basically, two series can be either asymptotically independent or dependent. The former type of dependence implies that in the infinitely large realizations of the series never occur simultaneously, while the latter implies the opposite. Therefore, a shift in the type of asymptotic tail property from independence to dependence reflects an increase in contagion. The second dimension is associated to changes in the extremal dependence measure (contagion) corresponding to a given the type of asymptotic tail property. These issues will be clarified further in Section III.

The main findings of this study are listed below:

- Bear market contagion during the second half of the past decade is stronger than bull market contagion within market classes, across markets, and within regions. This finding, which is consistent with those of earlier empirical studies, highlights the asymmetric nature of the financial transmission mechanism across stock markets.

- The successive crises experienced during the second half of 1998 –the debacle of Long Term Capital Management, the Russian debt crisis, and the Brazilian currency crisis– constituted major shocks with a lasting impact on the global financial system, as they prompted sustained increases in bear market contagion. In contrast, the 1994 Mexican crisis appeared not to have a major impact on contagion, while the 1997 East Asian crisis had only a regional impact.

- Under the assumption that increased financial integration increases a stock market's vulnerability to contagion, Latin American stock markets are more closely integrated with mature stock markets than East Asian markets. At the regional level, Latin American stock markets have become more integrated during the past decade, as measured by the upward trend in both bear and bull market contagion. In contrast, the financial integration of East Asian stock markets has remained roughly the same.

- Emerging stock markets are mostly affected by contagion with the United States and the United Kingdom. In particular, contagion with the United States is particularly strong in the Latin American region. Contagion between Japan and emerging stock markets is mostly neligible.

- Latin America is the only region where the number of asymptotically dependent country pairs has increased during bear market episodes. This evidence suggests a stronger shift in the downside transmission mechanism in the region, as stronger contagion is reflected not only in higher values of the extremal dependence measures but also by changes in changes in the asymptotic tail properties. There is nonetheless a decline in bear market contagion between Argentina and the rest of Latin America toward the end of the sample period.

- Contagion measures and 5-year rolling window equity market returns correlation are not highly correlated, with Latin American stock markets being the only exception. Hence, reliance on simple correlations as a measure of contagion could be misleading.

The findings above point toward an overall increase in contagion worldwide on average between 1987 and 2001, especially across mature markets, between mature and Latin American stock markets, and within Latin America. Though this paper does not explore possible explanations for these results in depth, there are a number of potential hypotheses that could explain the results. One hypothesis is that financial and trade linkages have strengthened considerably because of increased globalization. Therefore, changes to economic fundamental factors are transmitted more rapidly than in the past, leading to increased price comovements and contagion. In particular, increased dependence on complex financial instruments such as sovereign default swaps, and arbitrage strategies by hedge funds may have increased the exposure and vulnerability of financial institutions in mature markets to emerging markets. One notable example was the systemic risk posed by LTCM, whose demise was linked to adverse price movements in emerging markets. Another possible hypothesis is that in the absence of changes in fundamental economic factors, herding behavior among investors may lead to bouts of irrational exuberance and unjustified panics, increasing the synchronization of financial prices. Anecdotal evidence may support the herd-behavior explanation, as the importance of dedicated investors relative to cross-over investors in emerging markets has been declining in the last years. Therefore, the proportion of informed investors in emerging markets may have been shrinking steadily, increasing vulnerability to shifts in market sentiment.

The rest of the paper is organized as follows. Section II reviews the literature. Section III provides a concise overview of extreme value theory and the empirical methodology used in this study. Section IV describes the results obtained in detail. Section V concludes.

II. RELATED LITERATURE

The reliance on extreme value theory rather than correlation analysis is motivated by the limitations of the latter approach.[4] In fact, simple correlation analysis can be deceptive when studying financial market dependence, as shown by Boyer, Gibson, and Loretan (1999), and Embrechts, McNeil, and Straumann (1999).[5] Boyer et al showed analytically and numerically that data with stationary distributions could generate spurious correlation breakdowns. Their results invalidate the common practice of splitting a sample according to the realized values of the data in order to identify different correlation regimes. Embrechts et al showed that even in the static case, when the multivariate distribution characterizing financial time series do not change in time, the use of correlations as dependence measures is justified only for multivariate normal distributions. Otherwise, correlations fail to reveal the multivariate dependence structure: zero correlation does not indicate independence, and perfectly dependent variables do not exhibit absolute unity correlation. Moreover, correlations are not invariant under monotonic data transformations.

Extreme value theory has been increasingly used to study the tail behavior of univariate financial time series.[6] However, the application of multivariate extreme value theory to study the joint probability or dependence of extreme realizations (extremal dependence) in financial markets has been more limited. Starica (1999) proposed a spectral measure method to estimate the probabilities of joint extreme returns in series generated by models with constant conditional correlation models, a family that encompasses GARCH models. Application of this method to high frequency data on EU currencies uncovered a high level of dependence between extreme returns. Longin and Solnik (2001), using monthly data for the period January 1959 to December 1996, found that the pair-wise correlation of extreme returns between the United States, and the United Kingdom, France, Germany and Japan increases in bear markets but not in bull markets.

Hartmann, Straetmans and de Vries (2001) studied asset return linkages during periods of stress across stock markets, bond markets, and stock-bond contagion in the G-5 countries. These authors suggested that contagion was better understood from the perspective of the probability of joint crashes. They found that market crashes were rare occurrences, but once one market crashed, the conditional probability of a crash in a different market crash was about one in five. Similarly, Bae et al (2000) suggested that contagion is better measured by

[4] Hilliard (1979), Eun and Shim (1989), Roll (1988, 1989), Bertero and Mayer (1990) and Baig and Goldfjan (1999), among others, are examples of the correlation analysis approach.

[5] See also Forbes and Rigobon (forthcoming).

[6] See Jansen and de Vries (1991), Longin (1996), Jondeau and Rockinger (1999), Phoa (1999) and Tsay (1999) among many others.

the joint probability of co-exceedances in more than one market. These authors used a multinomial logistic regression, an approach commonly used in epidemiology studies, to estimate contagion across countries within a region and across regions rather than extreme value theory, though. They found that contagion could be explained by interest rates, changes in exchange rates, and conditional stock return volatility. Quintos (2001) constructed a measure of extremal correlation that does not depend on the specification of a dependence (copula) function and used it to analyze contagion, defined as significant extremal correlations changes in exchange rates, between Thailand and a number of Asian countries.

Finally, Poon, Rockinger and Tawn (2001) noted that the studies described above assumed asymptotic dependence. Intuitively, two series exhibit asymptotic dependence (independence) when in the limit, tail realizations of both series always (never) occur together. If the series analyzed are asymptotically independent, the use of conventionall extreme value theory methods would overestimate the degree of extremal dependence. Poon et al described simple methods, first developed by Coles, Heffernan and Tawn (1999), to test whether two series are asymptotically independent, and to estimate their extremal dependence. The methods are applied to daily stock market returns in the United States, the United Kingdom, Germany, France and Japan, with the sample divided in three different periods so that extremal dependence in bear markets and bull markets can be analyzed. They found that asymptotically independence characterized most of the pair-wise combinations of stock returns, and that extremal dependence was much stronger in bear markets than in bull markets.

This paper, which also follows the methodology proposed by Coles et al, is closely related to the work of Poon et al referred above. The main differences are as follows. First, a wider set of equity markets is considered in this study and special attention is paid to the transmission of shocks across different market classes, e.g., mature and emerging. Second, the use of 5-year rolling window estimates of contagion permits tracking their historical evolution without assuming a priori that structural breaks took place in certain periods. Finally, the behavior of contagion measures is evaluated vis-à-vis the behavior of simple equity returns correlation, a measure widely favored in the policy-making community, to assess whether they convey the same amount of information. The next section proceeds to describe the theory and empirical methodology used in this study.

III. Theory and Empirical Methodology

Although the rapidly expanding statistical literature on bivariate extreme value theory offers a number of alternative EVT measures, as described in Malevergne and Sornette (2002), the preferred measure of extremal contagion adopted in this paper is the one first proposed by Coles, Heffernan and Rockinger (1999) since it accounts for the asymptotic properties of the tail distributions. Coles et al suggest a two-step approach to estimate extremal dependence. The first step is to determine whether two series are asymptotically independent, i.e., the type of asymptotic joint tail distribution that govern the behavior of the series in the limit. Intuitively, two series are asymptotically independent (dependent) when infinitely large realizations of each series never (always) occur simultaneously. Notice, though, that asymptotically independence does not preclude the simultaneous realization of large but finite realizations. After the asymptotic properties are determined, Coles et al propose two different dependent measures, $\bar{\chi}$ and χ, for the case of asymptotically independent and dependent series respectively.

This methodological framework implies that equity return contagion between two countries can be measured along two dimensions. The first dimension of contagion is associated to changes in the asymptotic properties of the joint tail distribution of equity returns. In fact, contagion is stronger between two countries if the equity return series are asymptotically dependent since it implies that very large equity return realizations in both countries occur simultaneously. In contrast, asymptoticall independence implies that very large equity return realizations never occur together. Hence, for two countries with a previously asymptotically independent joint tail distribution, contagion increases if the joint tail distribution becomes asymptotically dependent. Moreover, an increase in the number of country-pair returns exhibiting asymptotically dependence suggests increased contagion world-wide, as structural changes in the transmission mechanism lead to changes in the asymptotic properties of the joint tail distribution. The second dimension is associated to changes in the the dependent measure when the type of asymptotic tail property remains unchanged. In this case, an increase in contagion between two countries is reflected in an increase in the dependence measure rather than changes in the joint tail distribution. Keeping these observations in mind, we proceed to explain the methodological framework below.

Given two positive random variables, X and Y, it is natural to relate their extremal dependence to either their limit conditional probability:

$$\lim_{x,y\to\infty} \Pr(X > x \mid Y > y), \tag{1}$$

which measures the probability of an extreme realization of X conditional on the realization of an extreme realization of Y; or the joint survivor function defined as:

$$\lim_{x,y\to\infty} \Pr(X > x, Y > y), \tag{2}$$

which measures the joint probability of large realizations of X and Y. In most empirical applications, the joint probability distribution function, $F(x, y) = Pr(X < x, Y < y)$, which is required to estimate the probabilities above is not known. However, it is possible to estimate their joint probability distribution if their univariate margin distributions are known using a *copula.*

The copula C is the unique function that relates the univariate marginal distributions of two random variables X and Y to their joint distribution (Nelsen, 1999):

$$F(x,y) = C\{F_X(x), F_Y(y)\} \quad (3)$$

where $F_X(x) = F(x,\infty)$ and $F_Y(y) = F(\infty, y)$ are the marginal distributions of X and Y respectively. Therefore, knowledge of the copula function C and the univariate distributions of X and Y is sufficient to have complete information on the joint distribution of X and Y. In practice, the copula function C can be either specified parametrically or estimate empirically from the sample distribution. In addition, copulas are invariant to non-decreasing transformations of the variables, so it is common practice to transform (X, Y) to uniform margins $(U, V) = (F_X(X), F_Y(Y))$. [7]

The information contained in the copula C about the extremal dependence of two random variables can be summarized by two dependence measures, χ and $\overline{\chi}$. The dependence measure χ is defined as:

$$\begin{aligned} \chi &= \lim_{u\to 1} \Pr(V > u \mid U > u) \\ &\sim \lim_{u\to 1} 2 - \frac{\log C(u,u)}{\log u} \\ &= \lim_{u\to 1} \chi(u) \end{aligned} \quad (4)$$

where $(U, V) = (F_X(X), F_Y(Y))$, and C is the copula that describes the joint probability of U and V. For independent variables, $\chi(u) = 0$; for perfect dependence, $\chi(u) = 1$. Notice that, in the limit $\Pr(V > u \mid U > u) = \Pr(U > u \mid V > u)$ so that extremal dependence between two random variables is symmetric. One of the shortcomings of using χ as the only dependence measure is that for large but finite values of u, estimates of $\chi(u)$ may be constant and positive even if the variables are independent in the limit, i.e. $\lim_{u\to 1} \chi(u) \to 0$.

When variables are asymptotically independent, the dependence measure χ is equal to zero by definition, so it does not contain information about the relative strength of dependence

[7] In recent work, Hu (2002) uses copulas to estimate dependent patterns in major financial markets. In contrast to the work presented here, as well as in the related literature section, Hu models the complete joint distribution of realizations rather than the tail realizations only. However, she has to assume a parametric model for the copula.

for large but finite realizations of the variables. Coles, Heffernan and Tawn (1999) suggest using the dependence measure $\overline{\chi}$ defined as:

$$\overline{\chi} = \lim_{u \to 1} \overline{\chi}(u), \tag{5}$$

where the function $\overline{\chi}(u)$ is defined as:

$$\overline{\chi}(u) = \frac{2\log(1-u)}{\log \overline{C}(u,u)} - 1, \tag{6}$$

with $\overline{C}(u,v) = 1 - u - v + C(u,v)$, and $\overline{\chi} \in [-1,1]$. Note that $\overline{C}(u,v)$ is simply the joint probability $\Pr(U > u, V > v)$. Therefore, if the random variables are asymptotically independent, it is possible to determine whether the extremal dependence is either positive or negative.

Estimates of $\overline{\chi}$ can be derived from the extreme return distribution of $Z = \min(X,Y)$. In fact, Ledford and Tawn (1996) showed that if the extremal values of X and Y have Frechet distributions their joint survivor function satisfies the condition:

$$\Pr(\min(X,Y) > z) = \Pr\{X > z, Y > z\} \sim L(z)z^{-1/\eta} \text{ as z} \to \infty,$$

where $L(z)$ is a slow varying function and $\eta \in (0,1]$ is the coefficient of tail dependence or shape parameter corresponding to the Generalized Pareto distribution of $Z = \min(X,Y)$:

$$G_{\sigma\eta} = \begin{cases} 1 - (1 + \eta(z-\theta)/\sigma)^{-1/\eta} & \text{if } \eta \neq 0,\ \sigma > 0 \\ 1 - \exp(-(z-\theta)/\sigma) & \text{if } \eta = 0,\ \sigma > 0, \end{cases} \tag{7}$$

where σ is the scale parameter of the distribution and θ is the threshold level above which extremal returns are defined. It follows that in the limit,

$$\overline{\chi} \to 2\eta - 1 \text{ as u} \to 1.$$

Therefore, estimation of $\overline{\chi}$ reduces to the estimation of the shape parameter of the extreme distribution of $\min(X,Y)$. This estimation can be accomplished in a number of ways as explained extensively in Embrechts, Mikosch, and Kluppelberg (1997). The dependence measure χ corresponds to the scale parameter σ holding $\eta = 1$, since it implies that $\overline{\chi} = 1$, and that the random variables are asymptotically dependent. In this case, $\chi = \sigma$ becomes the relevant extremal dependent measure.

The approach outlined above is the one used by Poon, Rockinger and Tawn (2001). Alternatively, given u, a simpler approach is to replace the empirical estimates of $C(u,u) = \Pr(U < u, V < u)$ and $\overline{C}(u,u) = \Pr(U > u, V > u)$ in equations (4) and (6).

This alternative approach is the one followed in this paper. In the context of our paper, extremal dependence measures are contagion measures, as they quantify the dependence between large negative (positive) equity returns in two markets.

Summarizing, the estimation of contagion measures requires the following steps. First, select the threshold value θ that determines the tail region. In this paper, the threshold value is 0.95, which means that only returns in the bottom (top) five percent quantile are considered in the analysis. It should be noted, though, that there are other ways to select the threshold value as suggested in Danielsson and de Vries (1997), Embrechts, Mikosch and Kluppelberg (1997) and Longin and Solnik (2000). Second, estimate empirically $C(u, u)$ and $\overline{C}(u, u)$ and calculate χ and $\overline{\chi}$. Third, if the null hypothesis $\overline{\chi} = 1$, can be rejected, then contagion is measured by $\overline{\chi}$. Otherwise, contagion is measured by χ.

IV. Results

The methodology described in the previous section is used to analyze weekly stock market returns in mature and emerging stock markets. Mature markets analyzed in this study include those of France, Japan, the United Kingdom, and the United States. Emerging markets include those of Argentina, Brazil, Chile and Mexico in Latin America, and Hong Kong SAR, Malaysia, Indonesia, the Philippines, Singapore, the Republic of South Korea, Taiwan Province of China, and Thailand. For each country, weekly stock market returns are calculated from the corresponding U.S. dollar-denominated Morgan Stanley Capital Index (MSCI) for the period December 31, 1987-October 25, 2001. Contagion measures for the bottom 5 percent negative returns, bear market contagion, and the top 5 percent positive returns, bull market contagion, were estimated using a fixed five-year rolling window. The length of the window permits including the Mexican crisis in 1994, the East Asia crisis in 1997, the Russian crisis and the collapse of LTCM in the second half of 1998, the Brazilian crisis in early 1999, and and the early stages of the Argentinian debt crisis in 2001.[8]

[8] The assumption of a fixed rolling window implies that the financial transmission mechanism, and hence contagion, changes over time and supposedly renders the results obtained here vulnerable to the criticism put forward by Forbes and Rigobon (forthcoming). Namely, using a fixed rolling window is equivalent to sorting out the data by the level of volatility. We offer two answers to this critique. First, on a practical level, the results presented here did not change substantially when the dependence measures were estimated recursively by increasing the sample size one observation at a time. Second, on an intuitive level, studies such as Chakrabarti and Roll (2000) suggest that crises are mainly characterized by dramatic declines in asset values rather than increased volatility, and hence, adjustments for volatility should not be applied.

This section evaluates how contagion in equity markets have evolved by first describing changes in the asymptotic properties of the tail distribution as measured by changes in the number of country-pairs displaying asymptotically dependence. Then, the section examines contagion trends by analyzing changes in the number of significant contagion cases, that is, those statistically different than zero for a 95 percent confidence level. Finally, the section concludes with a detailed examination of contagion within and across markets.[9]

Asymptotic Properties of the Tail Distribution

As explained above, contagion is stronger between two countries if their equity return series are asymptotically dependent rather than independent, as the former tail property implies the simultaneous realization of very large equity return realizations in both countries. Therefore, an increase in the number of country-pair returns exhibiting asymptotically dependence suggests increased contagion, as structural changes in the transmission mechanism lead to changes in the asymptotic properties of the joint tail distribution.

Figure 1 summarizes the main findings concerning changes in the asymptotic properties of the tail distribution. For all country-pairs analyzed, the number of asymptotically dependent cases have never exceeded thirty percent of all cases during the period under study, both for bear and bull market contagion. In the case of bear market contagion, the number of asymptotically dependent cases increased sharply in the second half of 1997 following the East Asia crisis due to increases in the number of asymptotically dependent cases between Latin America and both mature markets and East Asia. However, by the end-1998, the number of asymptotically dependent cases was almost neligible. It should be noted, though, that for Latin America, and to a lesser extent in mature markets, the number of asymptotically dependent cases has been increasing since end-1998 (Figure 2).

In the case of bull market contagion, the most salient feature is the increase in the number of asymptotically dependent cases in early 1996 due to increased dependence between mature markets and emerging markets and within emerging markets, with dependence measured by the greater number of cases classified as asymptotically dependent. However, briefly after the 1996 peak, the number of asymptotically dependent cases have been declining steadily and now it stands at the same level as in the case of bear market contagion. Interestingly, for any given period except during the East Asia crisis, asymptotically dependence is more prevalent during bull market contagion than during bear market contagion.[10]

[9] Because of space limitations, only selected figures have been included. A set of complete figures is available from the authors upon request.

[10] Results showing how dependence has changed for each individual country-pair during the

Figure 1: Number of Asymptotically Dependent Cases – Mature Markets

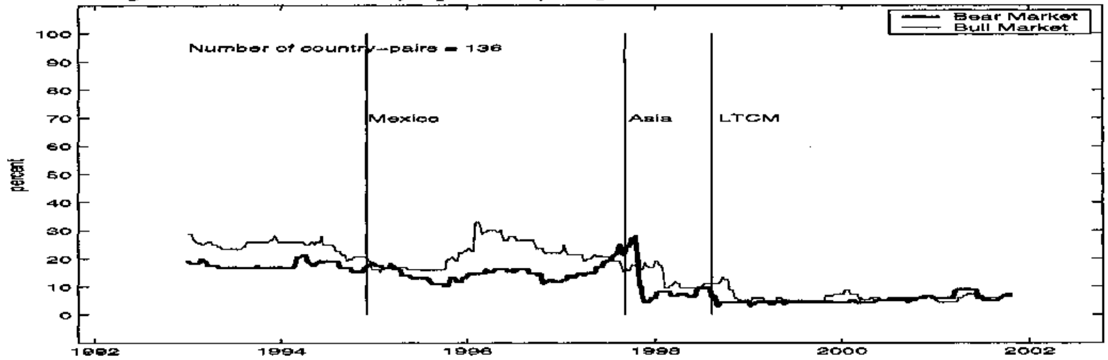
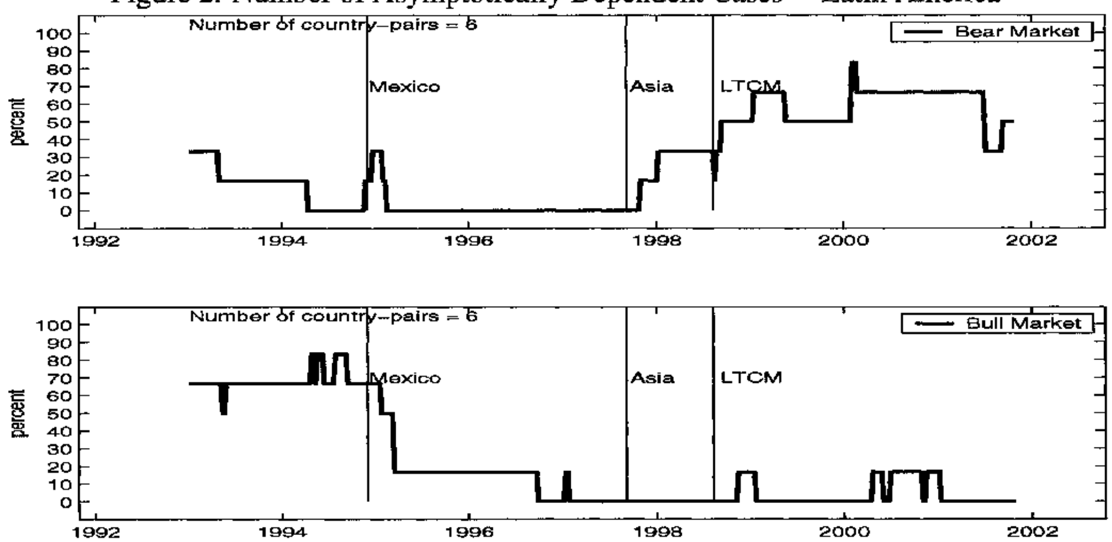


Figure 2: Number of Asymptotically Dependent Cases – Latin America



Is Contagion Significant?

A second way to assess contagion trends is to evaluate changes in the number of contagion cases that are statistically different than zero. Figure 3 shows the number of significant contagion cases as percent of all country-pairs analyzed.

In the case of bear market contagion, the data shows a sharp decline in the ratio of significant contagion cases to total cases from 40 percent in late 1995 to roughly 20 by mid-1997. The decline was reversed dramatically in the wake of the East Asia crisis, as

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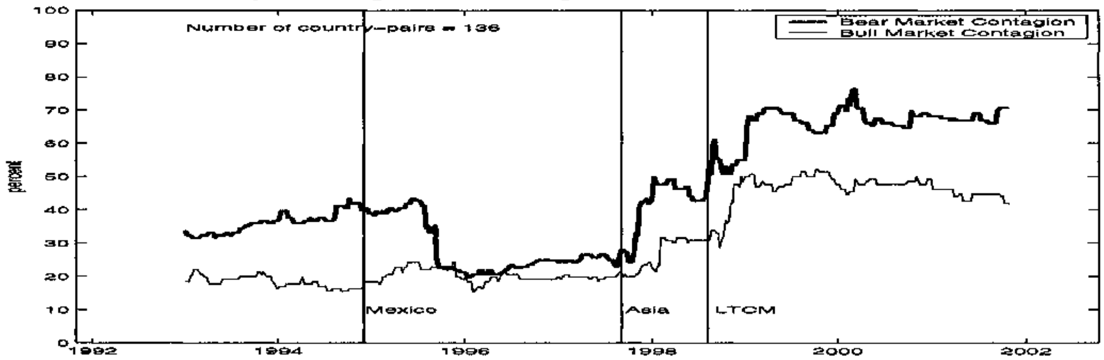
past decade, e.g., whether the countries' stock return series are asymptotically dependent or independent, were also obtained. However, no clear pattern worth reporting emerged.

Figure 3: Significant Contagion Cases – All Markets



significant contagion cases jumped upwards from 30 percent prior to the crisis to 50 percent by end-1998. The Russian GKO default in August 1998 and the LTCM debacle in October 1998 coincided with another increase of significant contagion cases by 10 percent to 60 percent. Finally, by the time of the Brazilian devaluation in early 1999, significant contagion cases reached 70 percent. This evidence suggests that overall, bear market contagion increased following the late 1990s crisis.

However, the empirical evidence varies widely within regions and across regions. For mature markets, only the 1998-99 crises led to increasing number of significant contagion cases. For Latin America, the Mexican crisis appears to be the catalytic event that led to a gradual increase in significant contagion cases, from 35 percent prior to the crisis to 100 percent by early 1996. For East Asia, significant contagion cases declined from 1995 to mid-1997, and increased sharply from 55 percent prior to the 1997 crisis to 95 percent by mid-1998.

Across regions, significant contagion cases between mature markets and Latin America only increased substantially in the second half of 1998, from 10 percent prior to the Russian GKO crisis to 50 percent by late 1998. They jumped upwards again to 70 percent in early 1999, and have increased gradually to 100 percent by the second half of 2001 (Figure 4). The pattern is quite different for contagion between mature markets and East Asia. The number of significant contagion cases experienced a short-lived increase in the aftermath of the 1997 East Asia crisis and started to decline afterwards only to reverse direction following the 1998-99 crises (Figure 5). With respect to contagion between Latin America and East Asia, the data shows dramatically that the East Asia crisis signaled a watershed event (Figure 6).

Figure 4: Significant Contagion Cases – Mature Markets and Latin America

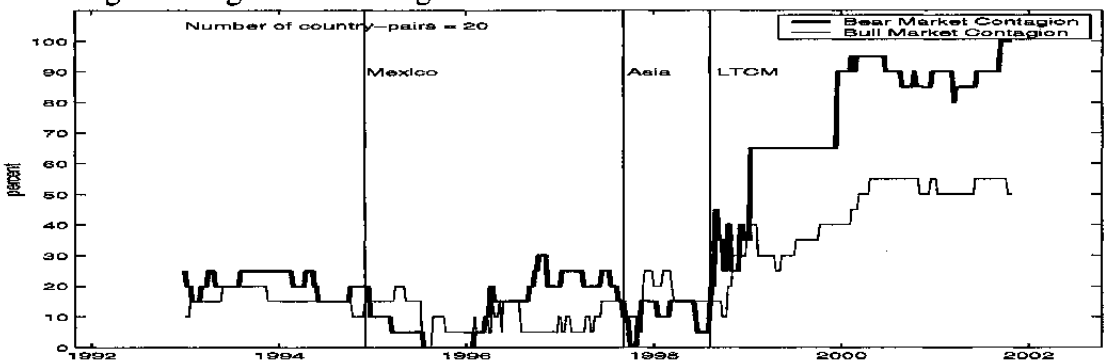


Figure 5: Significant Contagion Cases – Mature Markets and East Asia

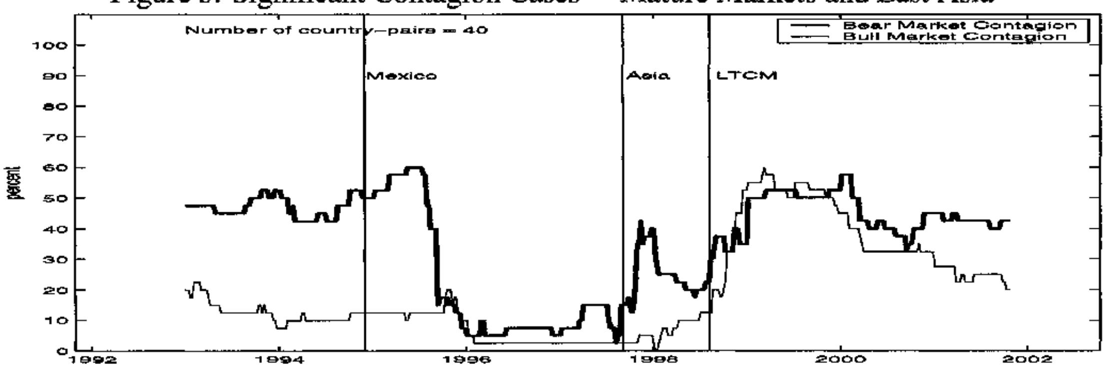
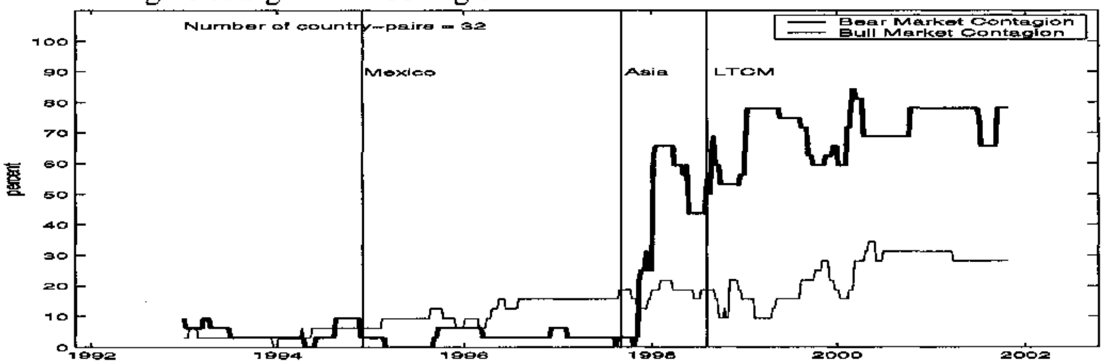


Figure 3 also shows that in the case of bull market contagion, the number of significant contagion cases increased worldwide in early 1999 due mostly to rising trends in emerging markets, and between mature markets and emerging markets. In contrast, the number of significant contagion cases between Latin America and East Asia did not increase significantly, while in the case of mature markets, they have declined since late 1995.

Contagion across mature stock markets

There are a number of distinctive bear market contagion patterns across mature stock markets. First, the extent of contagion of other mature markets with the United States was mostly flat and statistically insignificant prior to 1998 with the exception of some spikes in the 1995-96 period. It should be noted that contagion increased following the Mexican and Asian crises in 1994 and 1997 respectively, but remained statistically insignificant. Contagion between the United States and European stock markets changed dramatically following the rapid succession of financial crises in the second half of 1998. Indeed, from late 1998 to mid-1999, there was a steep increase in contagion, which leveled off around late 1999-early

Figure 6: Significant Contagion Cases – Latin America and East Asia



2000. There was a similar build up in bear market contagion between the United States and Japan, though contagion only became statistically significant in early 2001. By end-2001, contagion turned statistically insignificant once more.

Second, contagion between European stock markets exhibit a V-shaped pattern: contagion declined gradually from 1995 to 1997, leveled off during 1997-98, and from late 1998 onwards, it followed a similar pattern as contagion with the United States. It should be noted that contrary to contagion with the United States, contagion across European stock markets was statistically significant in the 1995-97 period, and became less significant in the post-1998 period. Finally, contagion between Japanese and European stock markets also exhibit the same V-shaped pattern that characterizes contagion across European. However, contagion has been mostly insignificant.

Some observations are worth noting regarding bull market contagion patterns in mature stock markets. First, bull market contagion between the United States and European stock markets was roughly constant, stronger than the corresponding bear market contagion, and statistically significant for substantial periods of time before 1997. Contagion declined gradually in 1997 and increased again starting 1998. During the post-1998 period, bull market contagion has been weaker than bear market contagion, and only contagion between the United States and France pair has failed to show statistical significance. Second, contagion across European stock markets has been roughly constant and statistically significant for most of the period under study. Finally, bull market contagion with Japan, that used to be statistically significant and stronger than bear market contagion before 1996, has been declining gradually since end-1992.

Contagion Between Mature Markets and Latin America

In Latin America, contagion with the United States only became statistically significant after the second half of 1998, a finding that reinforces the notion that the 1998 crises were major global shocks to the international financial system. Indeed, contagion with the United States climbed up to levels never seen before during 1999 and have remained roughly constant until the end of the sample period. Contagion with European stock markets have been increasing steadily, and have become statistically significant around mid-2000. Contagion with Japan is nonexistent. Because of the strong economic and financial linkages of Latin America with the United States, it is not surprising that contagion with the former is stronger than contagion with other mature stock markets.

Bull market contagion with the United States and European stock markets experienced increases in 1997 and 1998 for most Latin American stock markets. However, with the exception of contagion with the United States and Germany in the case of Argentina and Brazil, contagion has remained statistically insignificant. Contagion with Japan is not statistically significant, though estimates for Brazil, which increased significantly in 1998, are only marginally insignificant. On average, estimates of bull market contagion are lower than the corresponding estimates of bear market contagion.

Contagion Between Mature Markets and East Asia

In general, bear market contagion with mature markets has not been statistically significant for East Asian stock markets. By the end of 2001, the region's stock markets appear to be linked most closely to the United States and the United Kingdom. Overall, though, stock market linkages between East Asia and the developed world are weaker than those corresponding to Latin America, suggesting that the latter region is better financially integrated to the rest of the world.

Similarly, bull market contagion with mature markets has not been statistically significant during most of the period under study. By end-2001, there was only significant contagion between the United Kingdom and Hong Kong SAR. As in the case of Latin America, estimates of bull market contagion are lower than the corresponding estimates of bear market contagion. Interestingly, financial linkages between East Asia and Japan are not as strong as those between Latin America and the United States, as bear and bull market contagion is statistically insignificant.

Contagion within Latin America

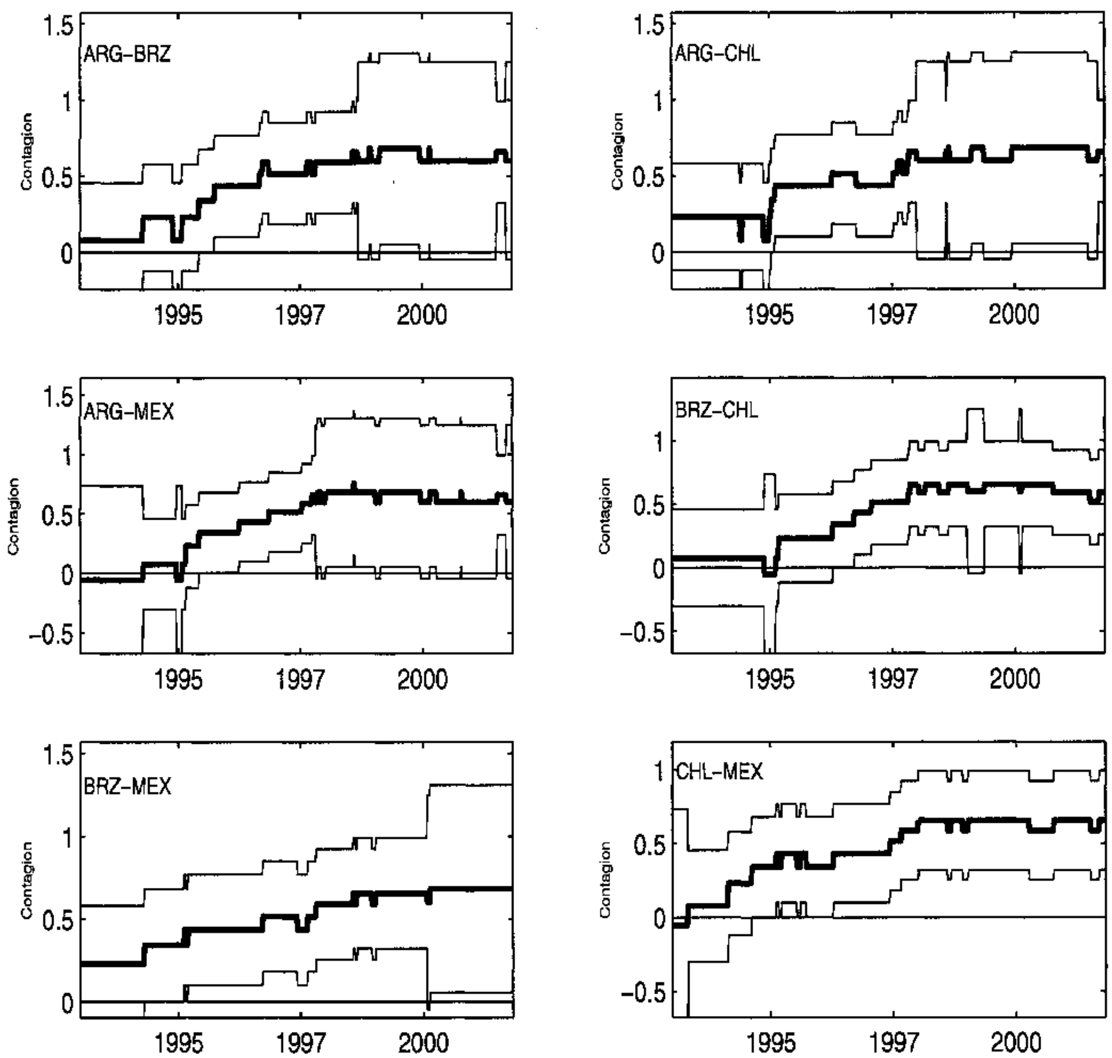
Within Latin America, bear market contagion increased steadily since 1992 to 1998, and then leveled off starting 1999 (Figure 7). During the period 1996-98, bear market contagion was statistically significant for most country pairs, and has remained significant with the exception of country pairs including Argentina. Nevertheless, contagion with Argentina has been only marginally insignificant from 1999 onwards, and in the case of Chile, became significant by end-2001. It is interesting to note that for the pairs Argentina-Brazil and Argentina-Mexico, contagion become significant in early 2001 but turned insignificant again by end-2001, a clear evidence of decoupling.

Bull market contagion across Latin American stock markets has been also trending upwards since 1998, with the only exception being the pair Argentina-Chile. Moreover, since 1998, contagion for almost all country-pairs has been statistically significant. In contrast to bear market contagion, there is no decoupling from Argentina for large positive market returns. As in the previous cases analyzed, bull market contagion is weaker than bear market contagion.

Contagion within East Asia

Contagion has been roughly constant and significant for most country pairs during the entire period under study in East Asia. Importantly, the 1997 East Asia crisis prompted an increase in contagion for a number of country-pairs for which contagion was not significant prior to the crisis, such as Hong Kong SAR-Korea, Hong Kong SAR-Taiwan Province of China, and Korea-Malaysia. Contagion with Singapore and Hong Kong SAR, the two most important regional financial centers, has been significant for most country-pairs since end-1992, and for all country-pairs since end-1997. In contrast with Latin America, there is no secular increasing trend in East Asia. Bull market contagion patterns are similar to those of bear market contagion albeit bull market contagion is weaker. This evidence suggests that financial transmission mechanisms across East Asian stock markets may have remained unchanged during the past decade.

Figure 7: Bear Market Contagion in Latin America



Contagion between Latin American and East Asian stock markets

Contagion between Latin America and East Asia was statistically insignificant prior to 1998. However, by late 1998 estimates of contagion increased sharply, and for some country-pairs including Argentina-Korea, Argentina-Taiwan Province of China, Chile-Hong Kong SAR, Chile-Thailand, and Mexico-Thailand, contagion became statistically significant. Contagion with Brazil, the major economy in Latin America, was only significant for Malaysia and Taiwan Province of China in 1999 and 2000 respectively. It is of interest to consider the degree of contagion between Argentina and Hong Kong SAR since both countries had currency board arrangements. In early 2000, contagion was significant but by mid-2001, decoupling took place and contagion turned insignificant. With few exceptions, bull market contagion across Latin American and East Asian stock markets have been statistically insignificant for the past decade. The exceptions are Argentina and Singapore, and Brazil and Hong Kong SAR, with contagion significant since 1998 and 2000 respectively.

Differences between Contagion Measures and Correlation Measures

Correlations between the contagion measures used in this paper and 5-year rolling window equity market returns conditional correlations suggest at times quite different patterns of contagion. (Table 1). For example, the correlation between bear contagion measures and conditional correlations between mature markets range between 0.20 (for Japan and the United Kingdom) and 0.91 (for the United States and the United Kingdom). Therefore, reliance on conditional correlations could lead to false alarms by overstating contagion risk not reflected in increases in extremal dependence measures, or create a false sense of security. The only exception is Latin America, where the correlation of contagion measures and simple correlations exceeds 0.93 for every pairwise combination of countries. However, even for the case of Latin America the use of simple correlations is not always validated since contagion measures and correlations sometimes move in different directions during short periods of time.

V. Conclusions

This paper has studied how contagion across equity markets has evolved during the past decade using dependence measures based on the joint behavior of co-exceedances of equity returns for pairwise combinations of equity market returns. These measures, which are based on extreme value theory, avoid the problems associated with the use of simple Pearson correlations. The results indicate that: (a) contagion patterns differ significantly within regions and across regions, with Latin America showing a secular increase in contagion not matched by other regions or countries; (b) contagion is higher for negative returns than for positive returns; (c) only the 1998 Russian and Brazilian crises led to a global increase in contagion; and (d) extremal dependence measures of contagion and simple correlation measures are not highly correlated, with the exception of Latin America, suggesting that the use of correlations as a proxy for contagion can at times be misleading.

Table 1. Correlation between Extremal Dependence Measures of Contagion and Conditional Correlations for Equity Markets

	USA	UKD	FRA	GER	JPN	ARG	BRZ	CHL	MEX	SGP	HK	IDO	KOR	MAY	PHL	TAW	THA
USA		0.91	0.85	0.83	0.64	0.75	0.93	0.91	0.82	0.36	0.11	0.02	0.94	0.60	0.60	0.80	0.40
UKD	0.51		0.50	0.64	0.20	0.81	0.76	0.92	0.94	0.14	0.76	-0.05	0.77	0.22	0.90	0.13	0.66
FRA	0.03	0.57		0.89	0.53	0.78	0.59	0.74	0.79	0.89	0.00	-0.61	0.92	0.70	0.87	0.60	0.66
GER	0.71	-0.16	0.28		0.50	0.91	0.75	0.90	0.94	0.77	0.38	-0.17	0.83	0.63	0.63	0.27	0.62
JPN	0.93	0.93	0.39	0.79		0.64	0.67	0.53	0.86	0.82	0.86	-0.53	-0.22	0.87	0.56	0.15	0.61
ARG	0.90	0.62	0.51	0.95	0.52		0.93	0.94	0.96	0.60	0.80	0.91	0.97	0.94	0.89	0.93	0.91
BRZ	0.88	0.44	0.28	0.83	0.87	0.97		0.96	0.98	0.58	0.14	0.57	0.96	0.62	0.79	0.52	0.84
CHL	0.67	0.21	-0.12	0.89	-0.26	0.50	0.98		0.94	0.85	0.47	0.84	0.83	0.80	0.79	0.86	0.62
MEX	0.72	0.81	-0.10	0.68	0.58	0.95	0.93	0.85		0.22	0.38	0.69	0.73	-0.11	0.74	0.13	0.83
SGP	0.82	0.63	0.28	-0.07	0.63	0.96	0.91	0.14	0.63		0.15	0.45	0.56	0.70	0.72	0.17	0.29
HK	0.23	0.85	0.20	0.45	0.80	0.32	0.92	-0.22	0.42	0.53		0.48	0.35	0.61	0.22	0.62	0.59
IDO	0.46	0.78	0.65	0.50	0.97	0.72	0.62	-0.02	0.63	0.89	0.81		0.81	0.24	0.70	0.41	0.58
KOR	0.86	0.58	0.58	0.80	-0.27	0.93	0.29	0.80	0.60	-0.11	-0.19	0.97		0.45	0.64	0.55	0.83
MAY	0.67	-0.08	0.77	0.17	0.46	0.75	0.09	-0.50	0.60	0.77	-0.42	0.64	0.26		0.72	0.76	0.59
PHL	0.24	0.82	0.78	0.14	0.75	0.17	0.86	0.34	-0.20	0.73	0.81	0.88	0.90	0.52		0.76	0.82
TAW	0.56	-0.05	0.29	0.55	0.63	0.42	0.29	0.24	0.25	0.58	0.87	0.86	0.32	0.43	0.46		0.43
THA	0.42	0.85	0.71	0.04	0.85	0.84	-0.46	-0.08	-0.37	0.25	-0.08	0.91	0.17	0.17	0.37	0.59	

Upper triangular matrix: Correlation between extremal dependence measures of contagion for large negative returns and conditional stock market return correlations.

Lower triangular matrix: Correlation between extremal dependence measures of contagion for large positive returns and conditional stock market return correlations.

Appendix I. Country Abbreviations Used in the Text

Mature markets:

USA = United States
UKD = United Kingdom
FRA = France
GER = Germany
JPN = Japan

Latin America:

ARG = Argentina
BRZ = Brazil
CHL = Chile
MEX = Mexico

East Asia:

HKG = Hong Kong SAR
IND = Indonesia
KOR = South Korea
MAY = Malaysia
PHL = Philippines
SGP = Singapore
TAW = Taiwan Province of China
THA = Thailand

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