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The International Crash of October 1987: Causality Tests

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Abstract

The paper analyzes lead-lag relationships for six major stock market indexes: New York S&P 500, Tokyo Nikkei, London FT–30, Hong Kong Hang Seng, Singapore Straits Times, and Australia All Ordinaries, for time periods before, during, and after the October 1987 market crash. Unidirectional and bidirectional causality tests are conducted by means of the Granger methodology. Practically no lead-lag relationships are found for the pre-crash and post-crash periods. However, important feedback relationships and unidirectional causality are detected for the month of the crash. There is also an increase in contemporaneous causality during and after the month of the crash. In general, our findings suggest that the October 1987 market crash probably was an international crisis of the equity markets and that it might have begun simultaneously in all the national stock markets.

I. Introduction

The international stock market crash of October 1987 has raised several important questions for financial analysts. To motivate our contribution, we identify three such questions:

(i) What were the causes of the crash?

(ii) What are the implications of the crash for international market efficiency?

(iii) How and why did the stock market crash propagate internationally?

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Numerous papers and commission reports have attempted to answer these and other questions.[1] Briefly, one could summarize the answers provided to the first question as belonging in two categories: macroeconomic and microeconomic causes. Among the macroeconomic causes, the existence of the twin deficits both in the federal budget and the balance of payments are cited most often. Portfolio insurance, speculative activities in derivative markets, such as futures and options markets, the introduction in the U.S. Congress of a tax bill that would have severely penalized corporate takeovers and leveraged buyouts, and the possible existence of speculative bubbles are listed as candidate microeconomic causes. In a well-documented survey paper, Roll (1989) reviews and critically evaluates some of these answers to the first question and concludes that empiricists have found it difficult to confirm the validity of any of these causes.

Since the first question is so difficult to answer, what can be said about the second? Efficiency in the conventional sense means that security prices, at any time, discount all information then publicly available about subsequent cash flows. This notion of market efficiency has been extended to international markets, whereby world stock market prices reflect all current information of world economic activity. Because the world markets received no obvious new information in the days immediately preceding the October 19, 1987, international crash, the academic community is challenged to consider the implications of such a crash to the notion of market efficiency. Friedman (1990) surveys some 50 papers that study U.S. market efficiency. Again, the evidence is mixed. There are numerous approaches that attack market efficiency, but there are also attempts to reconcile observed patterns of stock returns with standard notions of efficient markets.

The purpose of this paper is to analyze the third question. More specifically, we provide statistical evidence regarding the international propagation of the stock market crash. The questions of causality or lead-lag relationships are empirically investigated for several major national equity markets by means of Granger (1969) methodology. The paper is organized as follows. Section II describes the methodology used in testing the hypotheses. Section III describes the data and discusses the important problem of synchronization. Section IV presents the tests of cointegration. The empirical results and main findings of the causality tests are given in Section V. Finally, the last section briefly summarizes and concludes the paper.

II. Granger Causality Tests

The empirical tests are based on the Granger causality tests. These are essentially tests of the predictive ability of time series models. A time series $\{Y_t\}$ causes another time series $\{X_t\}$ in the Granger sense if present X can be predicted better by using past values of Y than by not doing so, considering also

[1]See, i.e., Blume and MacKinlay (1989), Brady et al. (1988), Greenwald and Stein (1988), Leland and Rubinstein (1988), and Miller et al. (1987).

other relevant information, including past values of X. More specifically, X is said to cause Y, provided some α_i is not zero in Equation (1),

$$(1) \qquad Y_t = \delta_0 + \sum_{i=1}^{m} \alpha_i X_{t-i} + \sum_{j=1}^{m} \beta_j Y_{t-j} + \mu_t.$$

Similarly, Y is causing X if some a_i is not zero in Equation (2),

$$(2) \qquad X_t = c_0 + \sum_{i=1}^{m} a_i Y_{t-i} + \sum_{j=1}^{m} b_j X_{t-j} + e_t.$$

If both of these events occur, there is feedback.[2] The test for causality is based on an F-statistic that is calculated by estimating the above expression in both unconstrained and constrained forms (full and reduced models),

$$F_1 = \frac{(SSE_r - SSE_f)/m}{SSE_f/(T - 2m - 1)},$$

where SSE_r, SSE_f = residual sum squares of the reduced and full models, respectively,
T = total number of observations,
m = number of lags.

F_1 follows a χ^2/m distribution and corresponds to a Wald test.[3]

This methodology is used to study potential links between international stock markets before, during, and after the crash of October 1987. Our approach differs from that in Roll (1988), who uses regression techniques and argues that the U.S. market was not the first to decline sharply on October 19, 1987. In effect, Roll (1988) indicates that non-Japanese Asian markets began a severe decline on October 19 on their time and this decline was echoed first by a number of European markets, then by North America, and finally by Japan.

III. Data Description

The data consist of daily closing prices for the following major equity market indexes: New York S&P 500, Tokyo Nikkei, London FT–30, Hong Kong Hang Seng, Singapore Straits Times, and Australia All Ordinaries. The prices have been collected from the *Wall Street Journal* for the time period May 1, 1987, through March 31, 1988.

To investigate the lead-lag relationships between the six stock market indexes before, during, and after the market crash of October 19, 1987, the data are divided into three sets:

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[2]A more detailed description of the several testable forms of Granger's causality can be found in Pierce and Haugh (1977), Geweke, Meese, and Dent (1983), and Guilkey and Salemi (1982).

[3]For details see, Guilkey and Salemi (1982), Schmidt (1976), and Geweke, Meese, and Dent (1983).

(i) May 1, 1987, through September 30, 1987: the period before the market crash;
(ii) October 1, 1987, through October 31, 1987: the period of the market crash;
(iii) November 1, 1987, through March 31, 1988: the period after the market crash.

Tests of unidirectional and bidirectional (feedback) Granger causal relationships are conducted in the three data sets, assuming 5 lags (5 trading days).

Testing for lead-lag relationships between international markets presents a problem of data synchronization due to time-zone shift differences. Addressing this issue is of primary importance in the execution and interpretation of the empirical tests conducted in this paper.

The data reported in the *Wall Street Journal* for the several indexes are closing prices for the same trading day. Since the Journal is published after the closing of the New York Stock Exchange, data for closing prices are available for all world exchanges. Exhibit 1 shows the trading hours of the national stock exchanges in Greenwich Mean Time, local time, and New York time. The last column of Exhibit 1 indicates that in any given trading day the closing prices for the several foreign exchanges analyzed in our sample are known by the time the NYSE closes for the day. With daily data available for the six national exchanges, daily returns are defined as

$$R_t = [\text{log of closing price index at } t\text{–log of closing price index at } t-1]\times 100,$$

where log denotes natural logarithm. Daily returns are computed for all six exchanges and a superscript is used to denote the return of a given exchange (i.e., R_t^{NY} and R_{t+1}^{T} correspond to the New York return at time t and Tokyo return at time $t+1$, respectively).

EXHIBIT 1

Market Time Tables

Stock Markets	Hours (Greenwich Mean Time)	Hours (Local Time)	Hours (New York Time)
Sydney	Midnight–2 15 a m / 4·00 a m –5 15 a m	10·00 a m.–12·15 p m / 2 00 p m –3 15 p m	7·00 p m –9:15 p m./ 11 00 p m –0 15 a m
Tokyo	Midnight–2 00 a m./ 4:00 a m –6 00 a m	9 00 a m –11 00 a m / 1 00 p.m –3 00 p m.	7 00 p m –9 00 p m / 11 00 p.m –1 00 a.m
Hong Kong	2 00 a m –4 30 a m / 6·30 a m –7 30 a.m.	10 00 a m –12 30 p m / 2.30 p m –3 30 p m	9 00 p m –11 30 p m / 1 30 a.m –2 30 a.m
Singapore	2 00 a m –4 30 a m / 6 30 a m –8 00 a m	10 00 a m –12 30 p m / 2 30 p m –4 00 p m	9 00 p m –11 30 p m / 1 30 a m –3 00 a m
London	9 00 a m –5 00 p m	9 00 a m –5·00 p m	4 00 a m –12·00 noon
New York	2·30 p m –9 00 p.m.	9 30 a m –4·00 p m	9 30 a m –4 00 p m

Source *Directory of World Stock Exchanges*

Now, let us suppose that a major world event occurs in Japan (such as a political crisis or changes in monetary policy, trade agreements, etc.) and is announced at 7:00 p.m. New York time on a given Tuesday. The Tuesday New York returns on the S&P 500 Index will not reflect this information. Observe from Exhibit 1 that at 7:00 p.m. New York time, Wednesday trading begins in Tokyo. Wednesday Tokyo returns will incorporate the information of this event and when Wednesday trading begins in New York, after 14½ hours from the announcement, New York Wednesday returns will also be affected. This illustrates that returns at time t in Japan affect returns in New York the same calendar day t. Therefore, a Granger regression investigating if Tokyo is leading New York looks as follows,

$$\text{(1a)} \qquad R_t^{NY} = c_0 + \sum_{i=1}^{m} a_i R_{t-i}^{T} + \sum_{j=1}^{m} b_j R_{t-j}^{NY} + e_t.$$

On the other hand, suppose that important U.S. economic data are released on a given day at 8:00 a.m. New York time. Their impact will be reflected in the same day returns in New York but at Tokyo's following day returns. This illustrates that New York returns at time t may affect returns in Tokyo at time $t+1$ (and not at time t). That is, a Granger regression postulating that New York is leading Tokyo looks like this, after adjusting for time-zone differences,

$$\text{(2a)} \qquad R_{t+1}^{T} = \delta_0 + \sum_{i=1}^{m} \alpha_i R_{t-i}^{NY} + \sum_{j=0}^{m} \beta_j R_{t-j}^{T} + \mu_t.$$

Because we are working with day-end prices, similar adjustments were made in testing for lead-lag relationships among other markets. Specifically, activities in the European market indexes today impact the U.S. market in the same calendar day but the Asian and Australian markets are impacted the following trading day. Also, today's activity in the New York market affects European, Asian, and Australian markets the following trading day. Finally, activities in the Asian and Australian markets impact the European and American markets the same calendar day. The complete details of these adjustments are motiviated by Exhibit 1, describing the market characteristics of the countries studied.

In Tables 1 and 2 the appropriate time dimension of the causality analysis is clearly specified. Observe that the dependent variable is indexed by τ, which takes the value t or $t+1$ depending upon the time zone shifts of the exchanges.

IV. Tests of Cointegration

It is also important to consider the cointegration among price movements on the different markets. In effect, Engle and Granger (1987) show that if two nonstationary variables are cointegrated, a vector autoregression in the first differences is misspecified. For example, if the natural logarithm of New York and Tokyo prices (i.e., $\text{Ln}\, P_{1t}$ and $\text{Ln}\, P_{2t}$) are both nonstationary (follow random walks), but the first differences of the natural logarithm of each price (i.e., $\text{Ln}\, P_{1t} - \text{Ln}\, P_{1,t-1}$ or $\text{Ln}(P_{1t}/P_{1,t-1})$, and $\text{Ln}\, P_{2t} - \text{Ln}\, P_{2,t-1}$ or $\text{Ln}(P_{2t}/P_{2,t-1})$), that is the returns, are stationary, it is said that prices are integrated of order one, denoted by $I(1)$. If each price is $I(1)$ and there is a linear combination of the New York prices and the Tokyo prices that is stationary, the two sets of prices are said to be cointegrated. The presence of cointegration can cause the Granger causality tests of Equations (1) and (2) to be misspecified. Therefore,

TABLE 1

Granger Causality Tests

Sample Period 1: May 1, 1987–September 30, 1987 (Pre-Crash Period)
Sample Period 2: October 1, 1987–October 31, 1987 (Month of the Crash Period)
Sample Period 3: November 1, 1987–March 31, 1988 (Post-Crash Period)

Models:

$$\text{I)}\quad Y_\tau = \delta_0 + \sum_{i=1}^{5} \alpha_i X_{t-i} + \sum_{j=1}^{5} \beta_j Y_{\tau-j} + \gamma\epsilon_{\tau-1} + \mu_\tau \qquad (X \rightarrow Y)‡$$

$$\text{II)}\quad X_\tau = c_0 + \sum_{i=1}^{5} a_i Y_{t-i} + \sum_{j=1}^{5} b_j X_{\tau-j} + d\epsilon_{\tau-1} + e_\tau \qquad (Y \rightarrow X)‡$$

Direction of Causality	τ	χ^2 for the Null $H_0\ \sum_{i=1}^{5}\alpha_i = 0,\ \sum_{i=1}^{5} a_i = 0$ Pre-Crash Period 5/1/87–9/30/87	Crash Period 10/1/87–10/31/87	Post-Crash Period 11/1/87–3/31/88
London → New York	t	0 7469	21 7581*	1 1091
New York → London	$t+1$	4 4202	29 9261*	0 4941
Singapore → New York	t	0 7734	3 8165	2 4689
New York → Singapore	$t+1$	0.9277	4 3614	0.6408
Hong Kong → New York	t	0 5106	230 0596*	1 5892
New York → Hong Kong	$t+1$	0 2310	24 1764*	0 5388
Tokyo → New York	t	0 2142	3 7410	1 1051
New York → Tokyo	$t+1$	1.0410	24 9239*	1.1160
Sydney → New York	t	1 8906	2 7351	0 0837
New York → Sydney	$t+1$	0 5907	9 4632	0 2905
Singapore → London	t	0 7281	14 7755*	1.8238
London → Singapore	$t+1$	0.4419	170 1973*	2 0772
Hong Kong → London	t	0 8406	6 2548	2 9746
London → Hong Kong	$t+1$	1.5336	269 6398*	0 7009
Tokyo → London	t	1 4324	124 5739*	1 0248
London → Tokyo	$t+1$	1 5884	188 9507*	2 9268
Sydney → London	t	2 0058	63 0430*	0 6733
London → Sydney	$t+1$	1.1865	15 5716*	1.0758
Hong Kong → Singapore	t	0 2109	48 0951*	2 9563
Singapore → Hong Kong	$t+1$	0 8129	3.0475	1.9582
Tokyo → Singapore	t	0 8226	33 6032*	2 2559
Singapore → Tokyo	$t+1$	2.5649	9 6592	2 7850
Sydney → Singapore	t	2 1629	71 4901*	0 3575
Singapore → Sydney	$t+1$	1 4586	5 2444	0 3258
Tokyo → Hong Kong	t	1 0193	4 1744	1 6568
Hong Kong → Tokyo	$t+1$	0 6221	77 4223*	3 5276
Sydney → Hong Kong	t	0 5004	8691 81*	0 9143
Hong Kong → Sydney	$t+1$	0 6621	52.9271*	0.5053
Sydney → Tokyo	t	2 7220	151 5554*	0 1318
Tokyo → Sydney	$t+1$	0 1407	70.2552*	0.1395

* Significant at the 5-percent confidence level, χ^2 crit at 5 percent = 11 07

‡ $\gamma = 0$, $d = 0$ if no cointegration

Equations I and II are Granger tests of causality. Equation I tests if X is causing $Y(X \rightarrow Y)$, Equation II tests if Y is causing $X(Y \rightarrow X)$ If both events occur there is feedback The variable $\epsilon_{\tau-1}$ corresponds to the error-correcting term if cointegration is present The index τ corrects for the synchronization problem by taking the values of t or $t+1$ depending upon the time zone shifts of the exchanges The null hypotheses of no causality are $\Sigma\alpha_i = 0$ or $\Sigma a_i = 0$ for Equations I and II, respectively. The test for causality is based on an F-statistic calculated by estimating Equations I and II in both unconstrained and constrained forms,

$$F_1 = \frac{(SSE_r - SSE_f)/m}{SSE_f/(T-2m-1)},$$

F_1 follows a χ^2/m distribution The computed F_1s are reported in the table for each pair of national markets

it is necessary to test for cointegration before running the causality tests. If cointegration is found, an error-correcting model must be constructed.

Engle and Granger (1987) propose several test statistics for testing the null of no-cointegration. In this paper, we use the Augmented Dickey-Fuller test.[4]

[4]Engle and Granger (1987) propose several ways of testing for cointegration. They formally state the test statistics, construct tables of critical values, and compare the powers of the tests. The simplest test of cointegration is the cointegrating regression Durbin-Watson, CRDW, which works

The Dickey-Fuller test of cointegration consists of running first the following cointegrating regression,

$$\text{(3)} \qquad \operatorname{Ln} P_{1t} = c_0 + c_1 \operatorname{Ln} P_{2t} + \epsilon_t,$$

and then running the following auxiliary Dickey-Fuller regression on the residuals of (3),

$$\text{(4)} \qquad \epsilon_t - \epsilon_{t-1} = -b_1 \epsilon_{t-1} + \mu_t.$$

The null hypothesis is $H_0: b_1 = 0$; that is, $\operatorname{Ln} P_{1t}$ and $\operatorname{Ln} P_{2t}$ are not cointegrated. The tests of cointegration yield mixed results with the null of no-cointegration being rejected more often for the month of the crash and the post-crash period than for the pre-crash period.[5]

Given that the results of the tests of cointegration are mixed, we proceed as follows: when the variables are not cointegrated, the causality tests are conducted by running the Granger regressions appropriately adjusted to correct for the synchronization problem (as indicated in Equations (1a) and (2a)). However, if the Dickey-Fuller statistic rejects the null, we conclude that the variables are cointegrated and, therefore, the Granger regressions are misspecified. We correct the regressions by incorporating the residuals from the cointegrating regression (3) as an additional independent variable in the Granger regression equations.[6] For instance, when cointegration is present and no synchronization problem exists between two markets, Equations (1) and (2) become

$$Y_t = \delta_0 + \sum_{i=1}^{m} \alpha_i X_{t-i} + \sum_{j=1}^{m} \beta_j Y_{t-j} + \gamma \hat{\epsilon}_{t-1} + \mu_t,$$

$$X_t = c_0 + \sum_{i=1}^{m} a_i Y_{t-i} + \sum_{j=1}^{m} b_j X_{t-j} + d\hat{\epsilon}_{t-1} + e_t,$$

where $\hat{\epsilon}_{t-1}$ are the residuals from Regression (3).

V. Results of Granger Causality Tests

The main results of the Granger causality tests are presented in Table 1. Column 1 gives the direction of causality (i.e., New York → London indicates that we are testing if New York leads London). Columns 2, 3, and 4 contain the

well with first-order systems. However, the critical values of the CRDW test are very sensitive to the particular parameters within the null. Engle and Granger (1987) do not recommend the use of the CRDW for economic data because, for most economic data, the differences are not white noise, making it difficult to know what critical value to use. Engle and Granger (1987) find that the Augmented Dickey and Fuller test has essentially the same critical values and same good power properties for first-order and higher-order systems. They also indicate that it is the most powerful test and, therefore, it is the recommended approach. The CRDW is simple and easy to implement. For statistical completeness, we have performed both tests.

[5]For the sake of space, the tables containing the results of the tests of cointegration based on the Augmented Dickey and Fuller tests are not presented in the paper. The CRDW was also used. Results from both tests are available from the authors upon request.

[6]We thank Professor Newbold from the Economics Department, University of Illinois at Champaign, for suggesting these error-correcting regressions.

TABLE 2

Tests of Contemporaneous Causality

Models:

$$\text{I)}\quad Y_\tau = \delta_0 + \sum\nolimits_{i=0}^{3} \alpha_i X_{t-i} + \sum\nolimits_{j=1}^{3} \beta_j Y_{\tau-j} + \gamma\epsilon_{\tau-1} + \mu_\tau \qquad (X \rightarrow Y)‡$$

$$\text{II)}\quad X_\tau = c_0 + \sum\nolimits_{i=0}^{3} a_i Y_{t-i} + \sum\nolimits_{j=1}^{3} b_j X_{\tau-j} + d\epsilon_{\tau-1} + e_t \qquad (Y \rightarrow X)‡$$

		α_0, a_0 Regression Coefficients, Standard Error and t-Statistics in Parentheses		
Direction of Causality	τ	Pre-Crash Period 5/1/87–9/30/87	Crash Period 10/1/87–10/31/87	Post-Crash Period 11/1/87–3/31/88
London → New York	t	−0 0214	2 3750	0 9026
		(0 1169)	(0 6512)	(0 1455)
		(−0 18)	(3 65)*	(6 20)*
New York → London	$t+1$	0 2010	0 8254	0 0724
		(0 0908)	(0 1664)	(0 0784)
		(2 21)*	(4 96)*	(0 92)
Singapore → New York	t	0 1082	1 5035	0 4403
		(0 0903)	(0 6190)	(0 1515)
		(1 20)	(2 43)*	(2 90)*
New York → Singapore	$t+1$	0 1316	1 2403	0 4504
		(0 1173)	(0 1640)	(0 0706)
		(1 12)	(7 56)*	(6 38)*
Hong Kong → New York	t	0 1751	0 3267	0 2734
		(0 1106)	(0.2127)	(0 1210)
		(1 58)	(1 54)	(2 26)*
New York → Hong Kong	$t+1$	0.1921	−0 0129	0 4192
		(0.0939)	(0 2836)	(0 0898)
		(2.05)*	(−0 04)	(4 67)*
Tokyo → New York	t	0.0950	−1 0920	0 4235
		(0.0582)	(4.3173)	(0 2041)
		(1 63)	(−0.25)	(2.07)*
New York → Tokyo	$t+1$	0 3959	0 7572	0 1429
		(0.1794)	(0 0358)	(0 0547)
		(2 21)*	(21 16)*	(2 61)*
Sydney → New York	t	0 0094	−2 2916	−0 0123
		(0.0039)	(1 4096)	(0 0393)
		(2 44)*	(−1 63)	(−0.31)
New York → Sydney	$t+1$	−2 3055	1.2459	0 4460
		(2 7503)	(0 0982)	(0 2900)
		(−0 84)	(12.69)*	(1 54)
Singapore → London	t	0 0160	0 5176	0 2430
		(0 0874)	(0.0891)	(0 0893)
		(0 18)	(5 81)*	(2 72)*
London → Singapore	$t+1$	0 1590	2 7929	0 4417
		(0 1200)	(1.9078)	(0 1267)
		(1 32)	(1 46)	(3 49)*
Hong Kong → London	t	0 1433	0 9555	0 1885
		(0 1047)	(0 3652)	(0 0737)
		(1.37)	(2 62)*	(2 56)*
London → Hong Kong	$t+1$	0 0086	−0 5452	0 7335
		(0 0976)	(0 6883)	(0 1407)
		(0 09)	(−0 79)	(5 21)*
Tokyo → London	t	0 1464	1 0098	0 0542
		(0 0541)	(0 4040)	(0 1396)
		(2 70)*	(2 50)*	(0 39)
London → Tokyo	$t+1$	0 1008	2.4605	0 3140
		(0.1941)	(0 4718)	(0 0813)
		(0.52)	(5 21)*	(3.86)*
Sydney → London	t	−0.0036	1.2766	−0 0058
		(0 0039)	(0 3435)	(0 0244)
		(−0.93)	(3.72)*	(−0 24)
London → Sydney	$t+1$	−1 7112	3 5627	0 5252
		(2 7689)	(0.4898)	(0 4747)
		(−0 62)	(7 27)*	(1 11)

continued on next page

TABLE 2 (continued)
Tests of Contemporaneous Causality

Direction of Causality	τ	α_0, a_0 Regression Coefficients, Standard Error and *t*-Statistics in Parentheses		
		Pre-Crash Period 5/1/87–9/30/87	Crash Period 10/1/87–10/31/87	Post-Crash Period 11/1/87–3/31/88
Hong Kong → Singapore	*t*	−0 0344	−0 6857	0 5615
		(0 1259)	(0 6353)	(0 0600)
		(−0 27)	(−1 08)	(9 36)*
Singapore → Hong Kong	*t* + 1	0 0470	−0 0725	0 0555
		(0 0819)	(0 3215)	(0 1800)
		(0 57)	(−0 23)	(0 31)
Tokyo → Singapore	*t*	0 0485	1 3411	0 6039
		(0 0702)	(0 2483)	(0 1356)
		(0 69)	(5 40)*	(4 45)*
Singapore → Tokyo	*t* + 1	−0 2650	1 0986	0 0167
		(0 1515)	(0 4330)	(0 0835)
		(−1 75)*	(2 54)*	(0 20)
Sydney → Singapore	*t*	0 0011	0 3486	0 0222
		(0 0047)	(0 3883)	(0 0296)
		(0 24)	(0 90)	(0 75)
Singapore → Sydney	*t* + 1	1 5707	1 2620	0 4546
		(2 2602)	(0 7778)	(0 3886)
		(0 69)	(1 62)	(1 17)
Tokyo → Hong Kong	*t*	0 0463	−0 3595	0 6643
		(0 0539)	(0 3560)	(0 1714)
		(0 86)	(−1 01)	(3 88)*
Hong Kong → Tokyo	*t* + 1	0 2740	0 8694	−0 0242
		(0 1924)	(0 1335)	(0 0640)
		(1 42)	(6 51)*	(−0 38)
Sydney → Hong Kong	*t*	0 0003	−0 5361	0 0493
		(0 0039)	(0 1627)	(0 0372)
		(0 08)	(−3 29)*	(1 33)
Hong Kong → Sydney	*t* + 1	3 7281	0 4831	0 5646
		(2 7480)	(0 2306)	(0 3100)
		(1 36)	(2 09)*	(1 82)
Sydney → Tokyo	*t*	0 0167	0 6315	0 0201
		(0 0066)	(0 0406)	(0 0205)
		(2 53)*	(15 54)*	(0 98)
Tokyo → Sydney	*t* + 1	−1 6641	6 0408	0 1758
		(1 5564)	(2 2934)	(0 5586)
		(−1 07)	(2 63)*	(0 31)

* Significant at the 5-percent confidence level
‡ $\gamma = 0$, $d = 0$ if no cointegration
Equations I and II are tests of contemporaneous causality The current values of *X* and *Y* are incorporated in the right hand side of Equations I and II, respectively Equation I tests if *X* is causing $Y(X \rightarrow Y)$, Equation II tests if *Y* is causing $X(Y \rightarrow X)$ If both events occur, there is a feedback The variable $\epsilon_{\tau-1}$ corresponds to the error-correcting term if cointegration is present. The index τ corrects for the synchronization problem by taking the value of *t* or *t* + 1, depending upon the time zone shifts of the exchanges The contemporaneous equation models I and II test if *X* and *Y* affect each other contemporaneously through α_0 or a_0, respectively

statistics for the null hypothesis of no causality ($H_0: \sum \alpha_i = 0$ or $\sum a_i = 0$) for the pre-crash period, month of the crash, and post-crash period, respectively. As the χ^2 statistics in columns 2 and 4 indicate, the null hypothesis of no-causality cannot be rejected and practically no lead-lag relationships are detected for the pre-crash and post-crash period.[7]

On the other hand, the χ^2 reported in Column 3 show a dramatic increase in causality for the month of the market crash, that is, for the time period October 1, 1987, through October 31, 1987. In fact, for the month of the crash, in 20 out

[7]Furthermore, for the periods before and after the market crash, most of the individual regression coefficients are not different from zero at the 5-percent level of significance. The complete tables containing all the individual coefficients, standard errors, and *t*-statistics are available upon request.

of the 30 lead-lag relationships analyzed, the null hypothesis of no-causality is rejected at the 5-percent confidence level. Bidirectional causality or feedback is detected among the following markets: New York and London, New York and Hong Kong, London and Singapore, London and Tokyo, London and Sydney, Hong Kong and Sydney, and Tokyo and Sydney. In addition, unidirectional causality is found among the following markets: New York leading Tokyo, London leading Hong Kong, Hong Kong leading Singapore, Tokyo leading Singapore, Sydney leading Singapore, and, finally, Hong Kong leading Tokyo.

The empirical results suggest that Tokyo played a passive role during the market crash of October 1987. In effect, no market lagged Tokyo except Singapore. On the other hand, no market led New York during the crash. However, with the exception of Tokyo, no market lagged New York, either. The results also indicate that Hong Kong played a leading role among the Asian markets by leading Tokyo and Singapore. Hong Kong, however, lagged the European market of London and showed feedback with New York. London and New York also exhibited feedback during the month of the crash.

Some studies, such as Roll (1988), have suggested that the equity market crash started in Asian countries other than Japan and from there spread to Europe, the United States, and finally reached Japan. On the other hand, Shiller (1987) and Shiller, et al. (1988) have indicated that the United States played a leading role. They postulate that the crash was initiated in New York and that the dramatic decline of U.S. stock prices spread the crash to other markets.

This paper provides evidence of the alleged passive role played by Tokyo during the market crash, but fails to confirm the alleged leading role played by New York or the non-Japanese Asian markets. In other words, our causality tests appear to reject both of the above hypotheses.

In order to get more insights about the relationships among the several markets before, during, and after the crash, we have run tests of contemporaneous causality. Models with contemporaneous causality can be constructed by including the current values of the independent variables X and Y in the right-hand side of Equations (1) and (2), respectively. The contemporaneous equation models imply that X and Y may affect each other contemporaneously through α_0 and a_0, respectively. The α_0 and a_0 regression coefficients are shown in Table 2. Little contemporaneous causality is observed for the pre-crash period. However, a substantial increase in contemporaneous causality is detected during and after the month of the crash.

The increase in feedback and contemporaneous causality among the national markets during the month of the crash suggests that the crash started more or less simultaneously in all countries. That is, according to our results, the market crash of October 1987 seems to have been a global crisis of the equity markets all around the world.

VI. Summary and Conclusions

The paper analyzes possible causal relationships among national stock markets around the October 1987 stock market crash. Lead-lag relationships among equity market indexes in six major countries are investigated: New York S&P

500, Tokyo Nikkei, London FT–30, Hong Kong Hang Seng, Singapore Straits Times, and Australia All Ordinaries. The study covers the time period May 1, 1987, through March 31, 1988. For analytical purposes, the data have been divided into three data sets: pre-crash period, month of crash, and post-crash period. Unidirectional and bidirectional causality relationships are analyzed based on the Granger tests.

Practically no lead-lag relationships are detected for the periods before and after the market crash. However, a dramatic increase in bidirectional and unidirectional causality is observed for the month of the crash. The empirical results show that during the month of the crash, Tokyo led no market except Singapore, and was also the only market lagging New York. No other national market led or lagged New York. New York also showed feedback with London and Hong Kong. London led Hong Kong, and Hong Kong led the other Asian markets. These results provide empirical evidence of the passive role played by Tokyo, but fail to confirm the leading role allegedly played by New York or the non-Japanese Asian markets during the October 1987 market crash.

Tests of contemporaneous causality indicate an increase of contemporaneous causality during and after the month of the crash. The increase in feedback and contemporaneous causality among the national stock markets during the month of the crash suggests that the crash probably started simultaneously in all the stock markets. Thus, the market crash of October 1987 seems to have been an international crisis of the equity markets.

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