TRANSMISSION OF INFORMATION BETWEEN STOCK MARKETS*

Amado Peiró, Javier Quesada and Ezequiel Uriel**

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ABSTRACT

This paper analyzes the effect of foreign stock price movements on domestic markets. The method we propose identifies, for each market in the sample, two different elements which have not been separated as yet: first, the importance of one market attributable to its intrinsic characteristics, which must be the same independently of the market receiving the influence. Second, how sensitive is the market index to the price variation observed in the preceding markets. An empirical analysis of the Tokyo, Frankfurt and New York stock market indexes provided meaningful qualifications to existing results.

RESUMEN

Este trabajo analiza el efecto del precio de las acciones extranjeras en los mercados nacionales. El método que aquí se propone identifica, para cada uno de los mercados estudiados, dos elementos distintos hasta ahora no diferenciados: primero, la importancia de un mercado atribuible a sus características intrínsecas, que deben ser las mismas independientemente del mercado que recibe la influencia. Segundo, la sensibilidad del índice bursátil a las variaciones de precio observadas en los mercados precedentes. Un análisis empírico de los índices de las bolsas de Tokio, Frankfurt y Nueva York, permite cualificar de forma significativa los resultados existentes en la literatura.

During the last years the main world stock markets have experienced a process of increasing internationalization, meaning a higher role for external phenomena on domestic markets. In particular, it is believed that price movements originating in certain markets are transmitted to other world markets. This belief has become quite extended, specially after the october 1987 crash, questioning the relative importance of domestic and external factors in changing stock prices.

Stock market linkages have received great attention in recent academic work particularly in relation with the convenience of using foreign markets to reduce risk exposure of portfolio management. Absence of perfect integration between markets would allow diversification and hence a more efficient treatment of risk. Nevertheless, not all studies have carefully dealt with the way information is incorporated into stock prices, taking into account the different times at which stock markets are open for trade. If markets are efficient, informational innovations produced at any time during a 24-hour period, will be reflected in the prices of the market closing immediately after. This fact ought to be taken into consideration by any analysis aiming at establishing the correct influence exercised by one particular stock market. This study provides a new methodology which enables us to clarify the ultimate causes behind the observed influence *exercised* by a specific market as well as the influence *received* from other markets.

In recent years, some studies have analyzed international financial market integration (stock as well as credit markets) using a great variety of techniques: crossed-correlation, regression and causality analysis as well as VAR techniques (see Bhoocha-oom and Stansell (1990), Becker *et al* (1990), Cheung and Mak (1992), Eum and Shim (1987), Chocran and Mansur (1991). Not all the time information is treated in an appropriate way and some stock markets appear to play a role in moving other market prices exceeding their own ultimate relevance; this is more a consequence of the timing of the business hours of the different markets, around the globe.

Simple correlation and regression analysis of stock market indices, ignoring the way information arrives to markets, may not be able to capture and disentangle from the observed rates of return the ultimate causes of variation. Following Fustenberg and Jean (1989) we distinguish two sources: (i) *global innovations*, news generated around the world and captured by stock prices in all markets. (ii) *Specific innovations*: information generated during a twenty four hour period that only affects the prices in one particular market. As an example, information on oil prices or on the value of the dollar would be considered global, and new regulation on domestic banking would be considered specific to a given stock market.

Under the efficiency hypothesis the daily rate of return on the index of a market should not be correlated with any information available at the closing of the market in the previous day. All rates of return must be related to innovations occurred during the previous 24-hour period. Hence, only innovations change prices. Once a market is closed for the day, the information that flows is gradually incorporated in the prices of the other markets open at the appropriate time. Thus, the closing index of a market will contain all information of global nature available until that moment. Hence, before the reference market opens for trade, there is accumulated information in the rates of return of the markets preceding it, which will be incorporated during the next trading hours.

Any market behaves as a *receptor* as well as a *transmitter* of information. Indeed, closing prices capture previous information and emanate news to the markets operating thereafter. So, each market is influenced by and influences all of the others as well. Since not all markets have the same size and importance it has been argued that the bigger the market the smaller the effect received from other markets, and the bigger the effects produced on them. Some studies have run regressions between rates of return in different markets, without paying attention to the time sequence in which markets operate. They estimate the same influence, say of New York, on Tokyo and Frankfurt, without considering the fact that Tokyo precedes Frankfurt; so that some of the actual influence of New York on Frankfurt would be taken by Tokyo. Hence, in order to attribute the correct influence induced by one market it is necessary to make the estimate of this effect dependent on the position of each market in the regression equation. Some studies have emphasized the relative position as the key variable in estimating market integration[1], ignoring market size differences and homogenizing markets by their proximity to others. They find a fading effect as the news travel around the globe, substituting country specificity by its relative position in the time sequence.

As opposed to other studies, the method we propose is able to identify, for each market in the sample, two elements which appear combined and have not -to our knowledge- been properly separated as yet: first, the importance of one market derived from its temporal location as a source of information, which must be the same independently of the market receiving the influence. Second, how sensitive the market is to global news observed in the preceding markets.

The paper is organized as follows. Section I provides descriptive evidence of the issue we are raising and reviews the way the literature has dealt with this problem. In section II we propose and estimate an econometric model describing also the data used in the empirical test. Finally, section III contains some concluding remarks as well as some suggestions for further research.

[1]See Furstenberg & Nam Jean (1989).

I. PRELIMINARY EVIDENCE ON MARKET LINKAGES.

Granger causality tests and transference functions -using co variability of interest rates- have been used to estimate financial market integration, Bhoocha-Dom and Stansell (1990); their basic methodology implies the assumption that causal relationship should imply absence of financial integration and international efficiency. Cheung and Mak (1992) use similar methodology to analyze the relationship between developed and Asian-Pacific markets. Cochran and Mansur (1991) also run Granger causality tests between the US and foreign equity market yields, not finding evidence of complete integration between different markets. Correlation analysis between the Tokyo and the New York markets appears in Becker, Finnerty and Gupta (1990). They use daily rates of return based on opening and closing data, where the opening value for each stock market index is taken after the accumulated information has exercised its influence on stock prices. A VAR dynamic simultaneous system for nine major national stock markets was estimated by Eun and Shim (1989), showing the US market as the most influential market.

Data used in our empirical work include daily rates of return on three markets: Tokyo's Nikkei (T), Frankfurt's Commerzbank (F), and New York's Dow Jones (N). These returns are computed as log differences. The sample period starts on January 3 1990, and ends in October 30 1992.

We have chosen three markets whose business hours do not overlap. Every date initiates right on the international date line, so that the first market closing on a given date is Tokyo. Four and a half hours after Tokyo closes, Frankfurt opens for a session of only three hours of duration. Two hours after Frankfurt closes, New York opens for trade for a period of six and a half hours, ending its session three hours ahead of Tokyo's start on the next date. Hence, along a 24 hour period there are three subperiods in which only one of the three markets is open and three subperiods in which the three markets are closed. For each day t, the sequence of observations starts with Tokyo, then Frankfurt and finally New York; so T_t precedes F_t and this, as well, leads N_t. However, N_t antecedes T_{t+1} , that is to say, the observed value of Tokyo's rate of return *on the next date.*

Table I reports crossed correlations between the rates of return of the three markets taking one lead and lag in each variable. It is interesting, to note that only some of these coefficients have a value significantly different from zero. The correlation between the rates of return on any two markets drops to a value very close to zero if one takes an extra lead or lag, meaning a positive test of the absence of any relation as theory predicts. If we take New York and Tokyo we see how significant is New York on date t-1 to move Tokyo on the next date t (.24) and how significant is Tokyo in leading New York on the same date t (.18). These values drop to (-.02) if we look for the influence of Tokyo (t) on New York one date later (t+1). We confirm the expected signs (positive) and direction of temporal causation.

TABLE I

INFLUENCE BETWEEN STOCK MARKETS
Lead & Lagged Market Rate of Return Crossed Correlations

	Nt-1	Nt	Nt+1	Ft-1	Ft	Ft+1
Tt-1	.18*	-.02	.1*	.33*	-.05	.07
Tt	.24*	.18*	-.02	.13*	.33*	.04
Tt+1	-.001	.24*	.18*	-.01	.13*	.33*
Ft-1	.27*	-.008	.04			
Ft	.27*	.27*	-.008			
Ft+1	.006	.27*	.27*			

*Significantly different from zero.

Tt, Ft, Nt: Daily rates of return on the Nikkei, Commerzbank and Dow Jones indexes respectively.
Sample period Jan 3 1990–Oct 30 1992.

All other crossed correlations between markets for different lags and leads are found not significant. Looking at the values in the table it looks as if the Frankfurt stock market was as influential (.27) on New York as the other way around; as if New York was more influential on Tokyo (.24) than Tokyo on New York (.18), finally, as if Tokyo's influence on Frankfurt (.33) was higher than the inverse relation (.13). A careful analysis will prove otherwise if we take into account the way information is produced and absorbed by markets. Market significance seems to depend on its role played as an indicator of information produced since the closing of the preceding market and during its business hours, while the influenced market is still closed.

To check this argument we show evidence on how the influence between different stock markets depends critically on the position they have in the temporal causal sequence. When we regress -using OLS- the return in New York on the return on Frankfurt and Tokyo on that same day, we find a decreasing influence from one market to the next one (see first column on table II). We also find an increase in the influence exercised by one market on another one if we take out of the regression markets placed in between. For example, Tokyo influence on New York grows from .053 to .096 -with an increasing significance as shown by the t-values in parentheses- as we drop Frankfurt out of the regression.

TABLE II

MARKET SIGNIFICANCE AND TIME ORDERING

Preliminar Regression Analysis

INDEPENDENT VARIABLE	DEPENDENT VARIABLE					
	Tt		F t		Nt	
Constant	−.001 (−1.43)	−.001 (−1.75)	−.0002 (−.45)	−.0005 (−1.10)	.0003 (.79)	.0003 (.87)
Ft					.184 (6.370)	
Tt			.203 (7.47)		.053 (2.65)	.096 (5.02)
Nt−1	.516 (5.99)		.293 (5.11)	.41 (7.63)		
Ft−1	.093 (1.60)	.196 (3.47)				

t−values in parenthesis. See notes on Table I.

Similarly, New York influence on Frankfurt grows from .29 to .41 when we drop Tokyo, the market operating in between. And finally, Frankfurt influence on Tokyo grows from .09 to .20 when we eliminate New York from the regression. Nevertheless, we should be very careful in drawing conclusions from these regressions due to the presence, in each equation, of common information captured by both regressors, since the news incorporated in the return of the more distant market will appear again captured by the regressor closer to the reference market. In the New York equation the global news produced since the closing of New York until the closing of Tokyo will show up, first, in Tokyo's return and, then, in Frankfurt's return. Thus, estimated parameters should not be interpreted as showing -say- more than three times as big the influence of Frankfurt than Tokyo on New York (.18 *versus* .053) because if we drop Frankfurt, Tokyo's influence almost doubles (.096 *versus* .053) -see the first two columns on table II.

Table II shows also an increase in the level of significance as the influencing market gets closer to the reference stock market. Furthermore, as efficiency would predict, we find no significance in the own lagged value of the rate of return, meaning that all information available at t-1 is incorporated in the closing price, having this price no predictive power on next period's return. Hence, the rate of return on one market depends only on the price movements occurred during the last twenty four hours. Looking at the estimated equations it looks as if New York depended more on Frankfurt than on Tokyo, and Tokyo more on New York than on Frankfurt. In this respect, it seems to exist a certain degree of interdependence and may be even of leadership between different markets, which deserves a more detailed attention.

One of the reasons why some small markets exercise a great influence on big markets following them is due to the the great amount of relevant information produced during or before their business hours while the influenced market is still closed for trade. If only one market is open while a lot of information is generated around the world, it will exercise a great amount of influence on the following markets. The longer the period and the higher the relevance of the political and economic activities taking place during such a time, the higher the influence exercised by such a market. The higher influence of New York on Tokyo than in the reverse direction might be due to the greater generation of information during the hours spanning from the closing of Tokyo until the closing of New York -15 hours of daylight in Asia, Africa, Europe and America- than in the period between the closing of New York and the closing of Tokyo -9 hours of daylight on the Pacific area.

II. PROPOSED MODEL AND ESTIMATION PROCEDURES.

Our starting point is Furstenberg and Nam Jean's 1989 model. They are very careful in analyzing the way information is generated around the world as different stock markets open and close sequentially. They estimate a four equation model -Tokyo, Frankfurt, London, New York- imposing a cross equation restriction that assumes an identical effect caused by each market if it occupies a similar position in the time sequence. That is to say, market A influence on market B will depend only on how far apart their closing times are, namely, how many other markets have closed in the mean time. This approach, although interesting in emphasizing the relevance of the market temporal position, goes too far in eliminating all other characteristics of the markets.

Considering a 24 hour period after the closing in time (t-1) of, say, the Tokyo market there are two types of effects caused by the arrival of news to be considered. First, there is the *specific* effect, that is to say, the new information produced during the whole period which is not incorporated in the closing prices of Frankfurt and New York. This information flows continuously along the 24 hour period but is only relevant for assets traded in the Tokyo market and it is captured uniquely in its price variation. Second, there is the *global* effect, news that are meaningful for all securities traded in all markets, affecting their closing prices. Consequently, all variation in the observed index should be the result of innovations taking place during the whole 24 hour period regarding global and specific effects.

Equations for the daily returns in each of the markets are as follows:

$$T_t = \alpha_T + \beta_{NT}N_{t-1} + \gamma_{FT}F_{t-1} + u_{1t} \qquad [1]$$

$$F_t = \alpha_F + \delta_{TF}T_t + \beta_{NF}N_{t-1} + u_{2t} \qquad [2]$$

$$N_t = \alpha_N + \gamma_{FN}F_t + \delta_{TN}T_t + u_{3t} \qquad [3]$$

where the explanatory variables are the daily returns observed in the other markets. So, $\beta_{NT}N_{t-1}$ represents the part of Tokyo's return due to global effects produced during the period running between Tokyo's closing on the former date and the closing of New York; $\gamma_{FT}F_{t-1}$ captures the part of Tokyo's return in date t due to global factors occurred during the period running between Tokyo's closing on the former date and the closing of Frankfurt; u_{1t} is the rest of the Tokyo return not explained by the other markets; that is, global effects occurred since Frankfurt's closing plus Tokyo specific factors come to present during the last 24 hours. We emphasize that the information generated after Tokyo's closing the day before until Frankfurt closing appears again in New York's return.

The error terms in the system [1-3] should be uncorrelated because the specific factors are independent by definition, and the global effects originated in each of the corresponding sub periods should not be correlated either since those sub periods do not overlap. To check whether the errors are uncorrelated, we run a Breusch and Pagan (1979) test. We calculate the statistic $T(r_{12}^2 + r_{13}^2 + r_{23}^2)$, where T is the number of observations and r_{ij} is the correlation coefficient of the least square residuals of equations i and j in system [1-3]. Under the null hypothesis of absence of correlation this statistic is distributed as a χ^2 with three degrees of freedom. The value obtained for this statistic (.5) means a marginal significance higher than .9, so that the sample evidence supports the acceptance of no auto correlation of the error terms.

Since error terms appear to be independent SURE estimation methods can be excluded. Nevertheless, we must be aware of the problems in which we may run if we estimate independently each of the equations of the system [1-3]. To face these problems we propose the following reparameterization,

$$\beta_{NT} = \beta\lambda_1 \qquad \gamma_{FT} = \gamma\lambda_1 \qquad [4]$$

$$\delta_{TF} = \delta\lambda_2 \qquad \beta_{NF} = \beta\lambda_2 \qquad [5]$$

$$\gamma_{FN} = \gamma\lambda_3 \qquad \delta_{TN} = \delta\lambda_3 \qquad [6]$$

Substituting in the system, we obtain

$$T_t = \alpha_T + \beta.\lambda_1 N_{t-1} + \gamma.\lambda_1 F_{t-1} + u_{1t} \qquad [7]$$

$$F_t = \alpha_F + \delta.\lambda_2 T_t + \beta.\lambda_2 N_{t-1} + u_{2t} \qquad [8]$$

$$N_t = \alpha_N + \gamma.\lambda_3 F_t + \delta.\lambda_3 T_t + u_{3t} \qquad [9]$$

λ_1, λ_2 and λ_3 can be interpreted as parameters showing market sensitivity to global factors, whereas β, γ, and δ are parameters showing the influence exercised by each of the three markets. To estimate the system [7-9] we have used the following procedure. We stack all observations in the following model.

$$\mathbf{y} = \mathbf{X}\phi + \mathbf{u} \qquad [10]$$

where

$\mathbf{y} = (T_1, T_2, \ldots, T_T, F_1, F_2, \ldots, F_T, N_1, N_2, \ldots, N_T)'$ is the vector of the observations of all endogenous variables, $\phi = (\alpha_T, \beta\lambda_1, \gamma\lambda_1, \alpha_F, \delta\lambda_2, \beta\lambda_2, \alpha_N, \gamma\lambda_3, \delta\lambda_3)'$ is the vector of parameters and $\mathbf{X}$ is the corresponding matrix of the regressors. To be able to identify the parameters we fix $\lambda_2 = 1$, estimating the model using Non Linear Least Squares.

Table III summarizes the empirical results contained in the estimation of our three equation model. We should start clarifying that the only meaning of the decomposition of the parameters as shown in the set of restrictions [4-6] is as a measure of the relative value of each of these coefficients for each market. For example, the ratios λ_1/λ_2, λ_1/λ_3 and λ_2/λ_3 can be interpreted as the relative sensitivity of the different markets towards global factors, and the ratios α/β, α/γ, β/γ, as the relative influence of the three markets.

TABLE III
THREE EQUATION MODEL ESTIMATION
Decomposition of Parameters

INDEPENDENT VARIABLE	**DEPENDENT VARIABLE**					
	Tt		Ft		Nt	
CONSTANT	-0.0010 (-1.8)		-0.0002 (-0.5)		0.0003 (0.5)	
F_{t-1}	0.14	γ: 0.10 (2.7) λ_1: 1.37 (4.5)				
N_{t-1}	0.47	β: 0.34 (5.5) λ_1: 1.37 (4.5)	0.34	β: 0.34 (5.5) λ_2: 1		
T_t			0.18	δ: 0.18 (6.1) λ_2: 1	0.11	δ: 0.18 (6.1) λ_3: 0.60 (3.7)
F_t					0.06	γ: 0.10 (2.7) λ_3: 0.60 (3.7)

t-values in parenthesis. See notes on Table I.

Along the third column -on the left side- we find the total effect caused on New York by Tokyo (0.11) and Frankfurt (0.06). The restrictions imposed on the coefficients allow us to decompose these parameters into two different parts. In the third column -right side- the parameters showing the influence on New York have one component peculiar to the influenced market (0.6), and another one linked to the characteristics of the influencing market (0.18 and 0.10 for Tokyo and Frankfurt respectively). On the other hand the influence caused by New York (row 2) is decomposed into a component measuring this market influence, (0.34) and a component depending on the influenced market (1 and 1.37 for Frankfurt and Tokyo respectively).

Our results determine New York as the most influential market with a coefficient of 0.34, *versus* 0.18 and 0.10 for Tokyo and Frankfurt respectively. According to our approach this means that most of the global innovations occur between the closings of Frankfurt and New York, while the smaller volume of global information is produced from Tokyo closing until Frankfurt's. Our estimates differ substantially of those presented in table 2. In particular, if we compare the Frankfurt equation of system [7-9] with the corresponding estimated OLS equation in system [1-3], we find New York receiving a higher coefficient (.34 *versus* .29) and Tokyo a lower value (.18 *versus* .20). This evidence confirms that some of the weight shown in system [1-3] attributed to Tokyo was really due to New York. Furthermore, the relative values of the λ's allow us to conclude that Tokyo is the most sensitive market of all three; more than twice as sensitive as New York and 40% more sensitive than Frankfurt.

A. Residual Analysis

According to the way information has been treated in this study, residuals may be decomposed in an interesting way. Let's take the residuals for the Tokyo market equation. These residuals capture Tokyo returns that are not explained by Frankfurt or New York, that is, global factors since New York closing as well as specific factors occurred during the last 24 hours.

$$\hat{u}_{1t} = \lambda_1 . \delta . T_t + v_{1t} \qquad [11]$$

The first term captures the global and the second term the specific effects. Notice that by making this decomposition, the global and specific components are not orthogonals, since v_{1t} is correlated with T_t. One possible solution could be to use in [11] estimates -instead of actual values- of T_t. However in graphs [1-6] the decomposition of the residuals shown in [11] is used in order to (i) decompose, in turn, the global effects and (ii) separate global from specific effects in all three markets.[2] Particularly, in graph [5] we show the decomposition of the global effects on New York, with higher influence exercised by Tokyo than by Frankfurt in spite of Frankfurt's higher proximity to New York. Furthermore, global effects for New York are very small relative to specific effects, as shown in graph [6].

[2]Further research in this point is in progress.

FIGURE 1

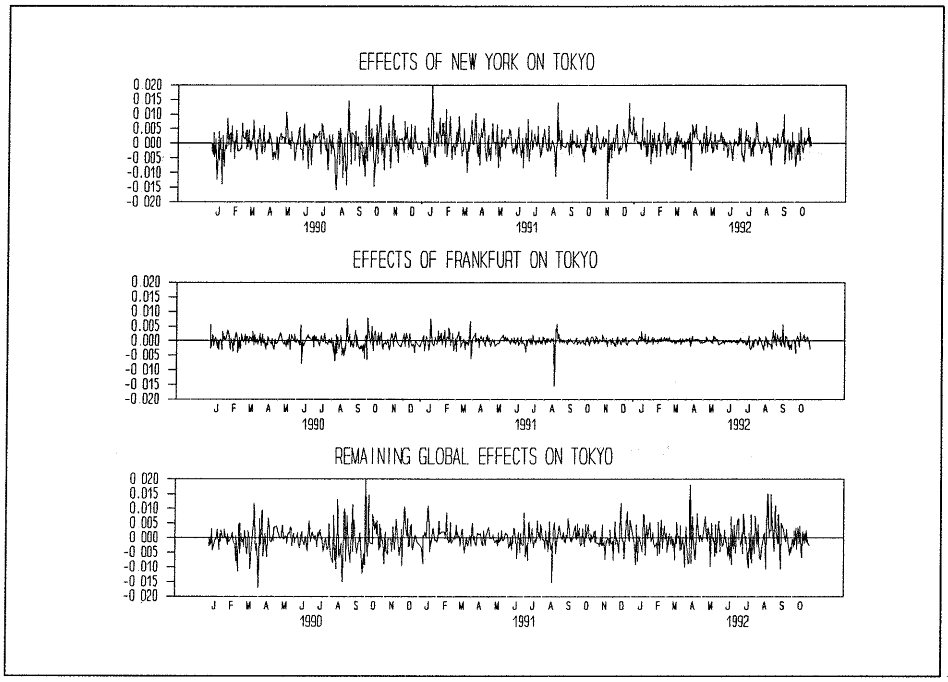


FIGURE 2

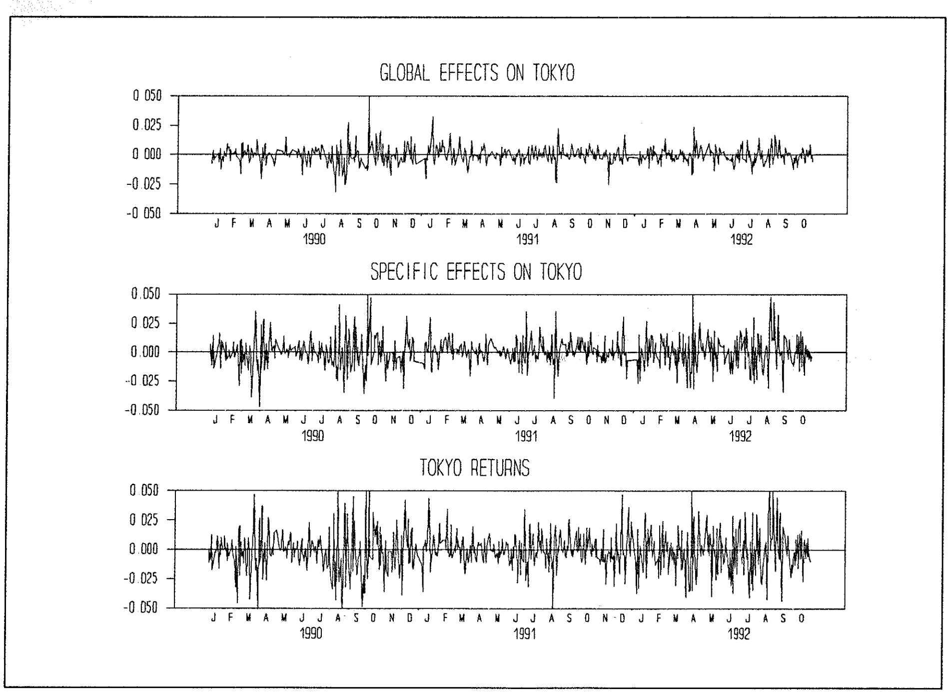


FIGURE 3

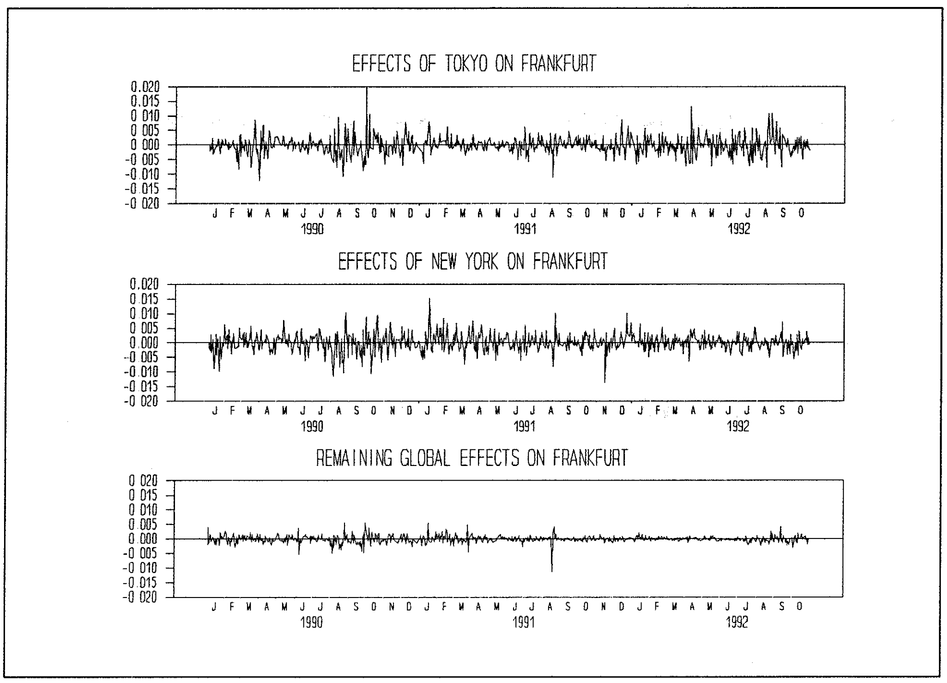


FIGURE 4

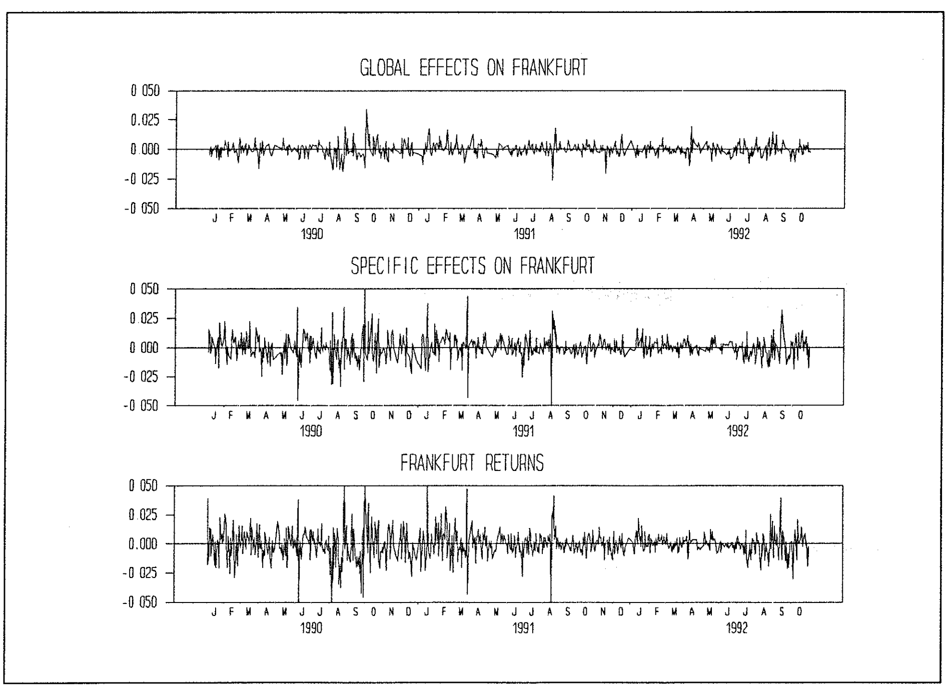


FIGURE 5

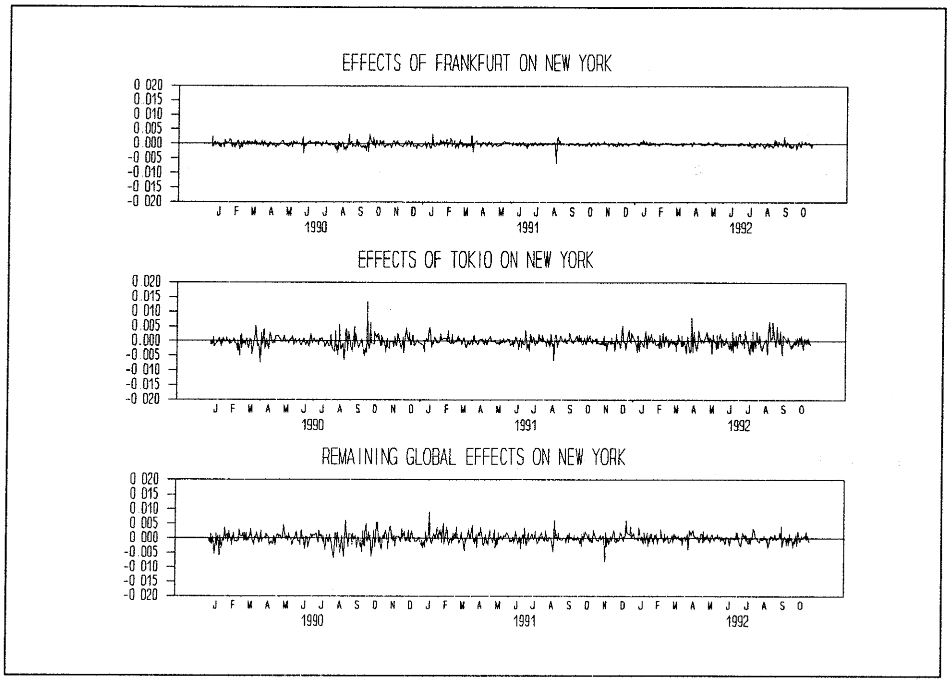
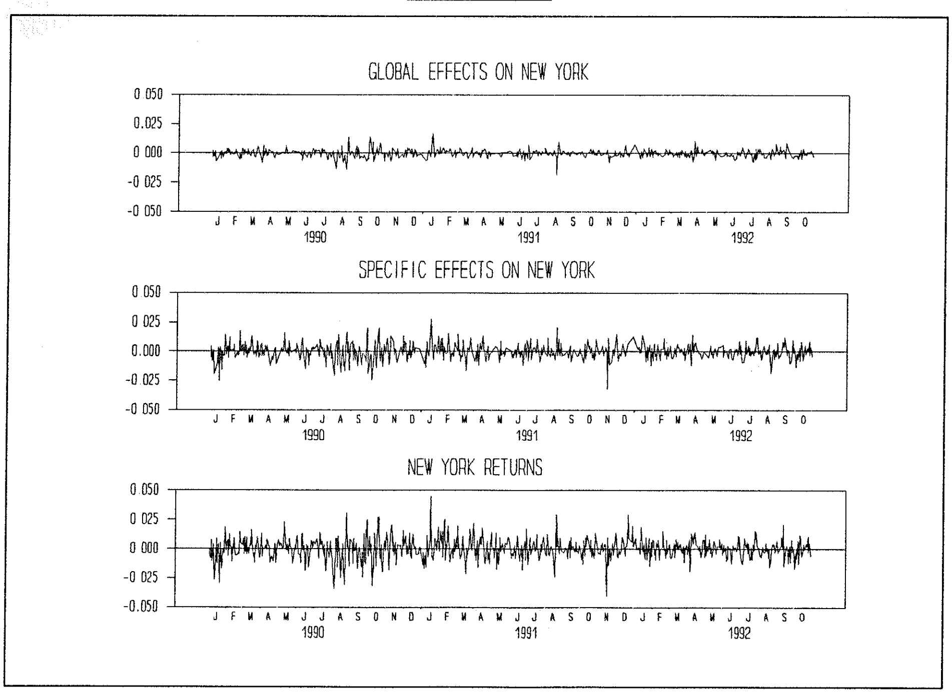


FIGURE 6



III. CONCLUDING REMARKS.

During the last years the internationalization process of the stock markets has intensified, questioning the possibility of reducing portfolio risk through diversification. This study analyzes the influence exercised by one market on other foreign markets as well as the influence received from such markets. The real cause for the observed stock price changes is the set of innovations occurring during two periods; indirectly, while the market is closed and through the price changes experienced by the preceding markets and, directly, occurring while the reference market is open. The model we propose allows us to identify two components of the influence transmitted by one market. One factor measures the sensitivity of one market towards the effects coming from foreign markets. The other factor measures the influence of each of the markets. In this way, the product of both factors -sensitivities and influences- quantifies the effective influence transmitted between the different markets. Empirical results provide a better understanding of the presence and degree of leaderships between markets.

One interesting finding concerning the error terms of the estimated equations is the possibility of separating the global from the specific effects on each market, offering a better understanding of the causal relationships and the degree of integration of different markets.

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