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An Empirical Study of the Dynamics of International Stock Markets Interdependence

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An Empirical Study of the Dynamics of International Stock Markets Interdependence

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This paper examines the interaction between international national stock markets using daily data and a VAR model. The results indicate that the speed of adjustment to equilibrium after a shock is about two days, indicating that markets are highly efficient at processing international information. Moreover, the US market appears to be the most important in the system, while Japan is very independent and does not have much effect on the other markets in the sample. Finally, the recent Asian financial crisis appears to have amplified the importance of the Asian markets to the rest of the global exchanges.

I. Introduction

The interaction between global stock markets is an important phenomenon in the world of finance. Within any given 24-hour period, dozens of different national stock markets are operating across a multitude of time zones and in a rapidly globalizing world economy. As a result, global equity exchanges based in separate countries are now increasingly influenced by domestic and international events and information. Given this, a growing portion of an individual market's daily return is determined by international information revealed prior to or concurrent with its opening.

Since stock markets are a leading indicator of the level of economic activity, their interdependence leads to some intriguing results. If a particularly violent economic shock with international ramifications were to occur, it would be picked up either first by the foreign stock market open at the time or the one residing in the country in which the disturbance originates. There are then leads and lags among international stock markets, as substantive new events and information affect all markets that are open concurrently, and are later transmitted to other markets opening subsequently. This means a complicated time-dependent structure exists between global stock markets that should efficiently transfer information internationally.

This paper is a study of the structure of the interdependence among six major international stock markets in Japan, Australia, Hong Kong, Germany, the UK, and the US. A Vector Autoregression (VAR) model is estimated using daily stock return data to examine the degree of efficiency and quickness with which markets adjust to new international information so as to

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examine the rationality of international portfolio diversification. In addition, an attempt is made to determine what markets are more closely related to others and whether there is a leader among the international equity markets. Finally, the effect of the 1997 financial crisis on this system is studied. Overall, the findings indicate that markets are informationally efficient; the US acts as a global leader; there is no distinguishable regional pattern of response; and the Asian crisis subsequently strengthened the role of Asian markets in the system.

II. Background

According to the efficient market hypothesis, in the absence of market imperfections, a stock index reflects all available information including that impounded in any other country's stock index. If true, "...there should be no systematic lagged inter-market adjustments long enough or large enough to exploit" (Koch and Koch, 1991, 231). This implies three things. First, there is an efficient transmission of information between international exchanges. Second, an increasing portion of each index's daily return will depend on events and information revealed abroad. Finally, because different markets are operating at different times during the same 24-hour period, there is a unique structure for transferring information that is based on various market's operating hours. The table below gives the opening and closing times of the six exchanges used in this study in Eastern Standard Time (EST).

Exchange	Opening Time	Closing Time
Australia	8:00 p.m.*	1:00 a.m.
Japan	8:00 p.m.*	2:00 a.m.
Hong Kong	10:00 p.m.*	3:30 a.m.
United Kingdom	4:30 a.m.	10:30 a.m.
Germany	5:30 a.m.	9:30 a.m.
United States	9:30 a.m.	4:00 p.m.
*Previous day in EST		
Source: Adopted from Sheimo (1999)		

As can be seen from this table, the first markets to open are Australia and Japan, followed by Hong Kong. These continue trading together throughout the night in EST and close before the markets open in Europe. The London Stock Exchange then opens an hour after the last Asian market finishes trading and is followed by Germany. By the time the various New York exchanges open, four of the five other major markets have already closed, while the UK and the US continue to trade simultaneously for another hour. Given these operating hours, there can be a discernible, time-dependent structure to the exchange of information throughout the world's markets that can be modeled.

Several papers have studied the interdependence among international equity markets, beginning with Agmon (1972). He uses monthly data from 1960 through 1966 and OLS to find that changes in share prices in Germany, the UK and Japan respond within one period to price changes in the US market index thus advancing the one-market hypothesis for global stock markets. Ripley (1973) employs factor analysis and average monthly stock price indices from 19 countries and finds that more than half of the movement in these indices is typically unique to the country of origin, but that it varies widely across nations. Hilliard (1979) uses spectral analysis on daily data in ten countries and finds that most intra-continental prices move simultaneously, while time-dependent, inter-continental prices do not seem to be closely related.

Eun and Shim (1989) use a VAR model and daily data for nine markets for the period 1979-1985 and find a substantial degree of interdependence among national stock markets. They also find that the US market is the most influential globally. Finally, they report that all responses to a shock are completed within two days, thus indicating informationally efficient international stock markets. Jeon and Von Furstenberg (1990) also use the VAR methodology but for four markets with daily data for 1986-1987. They examine the effect of the 1987 crash on the structure of international co-movements and conclude that the crash, along with expanding globalization, served to increase the transmission of innovations and reduce New York's leading role while increasing Japan's market independence. Koch and Koch (1991) use three-stage least squares and three separate years of daily data for eight markets and find evidence of growing interdependence among markets since 1972; a strong geographic tendency in market interaction; and few significant leads across foreign indices indicating rapid adjustment to relevant information.

Recently, research has centered on the use of the increasingly popular cointegration technique. Kasa (1992) examines the comovement of international indicies among five countries and over sixteen years of monthly and quarterly data using Johansen's test, and finds a single common stochastic trend among these markets. Chan *et. al.* (1992) employ the Engel-Granger cointegration test for five Asian stock markets and the US with daily and weekly data covering the period 1983-1987, and find no evidence of comovement. Gallagher (1995) uses weekly data from Ireland, the UK and Germany from 1983 to 1993 to test for cointegration over the entire period, and the pre- and post-1987 crash sub-periods using the Engel-Granger test. He finds no cointegration over the whole sample, but finds some evidence of it between Ireland and the UK and Ireland and Germany over the post-crash period. In addition, he finds unidirectional Granger causality flowing from the UK to Ireland and from Germany to Ireland, suggesting that these two markets lead the Irish one. Jan-Gerrits and Yuce (1999) use an error-correction model to examine four stock exchanges using daily data for the period 1990-1994. They discover that the US market exerts long- and short-run impacts on European markets and that European markets also influence each other in the long and short run.

III. Data and Methodology

Daily data are collected for six major stock market indicies at closing over the time period from January 3, 1995 to December 31, 1999. The S&P 500 index is used for the United States **(US)**, the DAX for Germany **(GERM)**, the Hang Seng for Hong Kong **(HK)**, the FTSE for the United Kingdom **(UK)**, the All Ordinaries Index for Australia **(AUST)** and the Nikkei 225 for Japan **(JAPAN)**. All the data are reported in local currency units and the closing price levels are logged to transform them into daily rates of return. In addition, the data are adjusted to account for the many differing days when one market is closed independently of the others. On such occasions, the previous day's value is used and a dummy variable is also created for each market taking the value of one when the market is closed and zero when it is open.

A six-equation VAR model is specified using these data. The justification for such a specification is based on the efficient markets hypothesis, which states that there is a dynamic interaction

between the various markets. Each equation in the VAR model expresses one country's stock market index as a function of the lagged values of its own and the other five countries' stock market indices. Thus, each equation indicates that whatever return there is depends on past returns at home and abroad. The lag length is chosen as the shortest interval necessary to remove autocorrelation from all the equations, a criterion that led to a lag of 15 days.

Before estimating the model, it is first necessary to test the variables for stationarity. This is done using the Augmented Dickey Fuller (ADF) unit-root test to test the series for I(2) vs I(1) first and then for I(1) vs I(0). The results, which are shown in Table 1, indicate that all variables are I(1). Given this, the data are first-differenced prior to estimation of the VAR model in order to make them stationary. An implication of this is that the resulting VAR model only captures the short-run relationship between the six stock markets considered. As is well known, one way to incorporate the long-run information into the model is to test for cointegration and use a Vector Error Correction (VEC) model if evidence of cointegration is found. The problem with the use of this approach in the present context is that cointegration is a long-run concept requiring long spans of time, whereas the data used here only cover five years.[1]

Table 1
ADF Tests of Unit Root

Natural Logarithm of Stock Market Return Indicies of Six Countries

Return Index	Null Hypothesis	Test Statistic	5% Critical Value	Lag Length	Decision
lnJAPAN	I(2)	-10.62856	-2.8663	6	Reject
	I(1)	-1.922343	-2.8663	6	Do not Reject
lnAUST	I(2)	-6.608027	-1.9399	15	Reject
	I(1)	-2.851140	-3.4189	10	Do not Reject
lnHK	I(2)	-7.400449	-2.8663	9	Reject
	I(1)	-1.159084	-2.8663	12	Do not Reject
lnGERM	I(2)	-6.878851	-2.8663	12	Reject
	I(1)	-1.948650	-3.4189	12	Do not Reject
lnUK	I(2)	-7.036588	-2.8663	12	Reject
	I(1)	-1.489829	-1.9399	8	Do not Reject
lnUS	I(2)	-11.65579	-2.8663	5	Reject
	I(1)	-2.943951	-3.4189	5	Do not Reject

Once the VAR model is estimated, various tests are performed to ascertain the structure of stock market interdependence. First, Granger non-causality tests are used to determine which stock markets influence the others and to test for regional influence among the countries. The results from this test are then compared to variance-decomposition results for all the markets, which help to determine how much of the forecast error variance of an individual index is accounted for by innovations in each of the six markets. This can give a better image of which

[1] With such a short span of time, should one find evidence of cointegration, it would perhaps not be indicative of the true long-run stochastic trend, but an aberration in the data over the past five years.

markets influence the others and whether there are any regional effects. Next, impulse response functions are estimated to determine how the indices respond to a positive, one standard deviation shock to each of the markets. The analysis is made time dependent by ordering the responses according to the different exchanges' operating times. This allows us to determine how a shock occurring in an eastern market might affect others opening later in the west, or how such a shock might cycle through from a western country to markets opening the next day. Analyzing the transmission helps to demonstrate what indices most influence others, and the speed with which markets adjust to foreign information. Finally, the sample is divided into the pre- and post-Asian financial crisis periods to determine if the impulse response functions and variances decompositions changed markedly between these two periods.

IV. Results

We begin with Granger non-causality tests in Table 2, which show the short-run structure of the international stock markets. As is evident from these results, the most dominant market is that of the US as it significantly Granger causes changes in all the foreign return indicies. The only other market that has nearly the same power is Hong Kong, although this result is not significant at very high levels of confidence. Surprisingly, the least influential market is Germany, which does not Granger cause any other market. The market most vulnerable to foreign information is the Japanese market, while the least susceptible are the United States and the United Kingdom markets. Further, there does not seem to be any evidence of the strong regional effect found by Koch and Koch (1991). While there is some linkage between Hong Kong, Japan and Australia, there is no bi-directional Granger causality between any pair of these three markets. The same holds for the European markets, as the UK and Germany do not Granger cause one another even in one direction. Interestingly, we also find the same evidence of the British Commonwealth effect that Eun and Shim (1989) report. This is shown in

Table 2
Granger Causality Tests

F-Statistics for Joint Significance of Lagged Log-Differenced Terms

Return Index	ΔlnAust	ΔlnJAPAN	ΔlnHK	ΔlnGERM	ΔlnUK	ΔlnUS
Lagged ΔlnAUST	–	1.61*	3.10***	1.12	3.32***	24.84***
Lagged ΔlnJAPAN	1.83**	–	1.72**	1.15	2.15***	5.40***
Lagged ΔlnHK	1.60*	1.26	–	1.41	3.30***	10.73***
Lagged ΔlnGERM	1.32	1.98**	1.90**	–	1.55*	14.44***
Lagged ΔlnUK	1.41	1.60*	1.94**	1.08	–	10.55***
Lagged ΔlnUS	1.09	1.16	2.47**	1.14	2.06***	–

* Significant at the 10% level
** Significant at the 5% level
*** Significant at the 1% level

the bi-directional causality between Hong Kong and the UK, and Australia and Hong Kong, and also the unidirectional causality from the UK to Australia.

Further insight into the international market structure can be gained from variance decomposition. Here, the order is from the first to last opening markets so that Japan is first, Australia second, Hong Kong third, UK fourth, Germany fifth and the US sixth. The decomposition begins with an innovation to the first opening market in a given day and ends with the last to

Table 3
Variance Decomposition

Return Index	Horizon	JAPAN	AUST	HK	UK	GERM	US	Total Foreign Market
ΔlnJAPAN	1	100	0	0	0	0	0	0
	2	89.18245	0.051221	0.125704	5.267415	0.178351	5.194859	10.81755
	5	88.06369	0.13418	0.27758	5.405888	0.75506	5.363604	11.93631
	10	85.69926	0.964925	0.871808	5.400909	1.259999	5.803095	14.30074
	20	83.55366	1.508475	1.401948	5.800894	1.403803	6.331216	16.44634
ΔlnAUST	1	5.671979	94.32802	0	0	0	0	5.67198
	2	3.931522	65.50338	0.042498	11.88555	0.55362	18.08343	34.49662
	5	4.068367	62.95554	2.83778	11.5145	0.736165	17.88765	37.04446
	10	4.693002	61.53271	3.174139	11.29662	1.304551	17.99898	38.46729
	20	5.144236	60.04308	3.793041	11.42695	1.781423	17.81126	39.95692
ΔlnHK	1	6.87494	8.026165	85.09889	0	0	0	14.90111
	2	6.085864	6.799817	71.76201	6.221342	0.01113	9.119837	28.23799
	5	5.903811	7.725373	70.3768	6.251842	0.26105	9.481125	29.6232
	10	5.87238	7.817998	68.61821	6.742386	0.921145	10.02788	31.38179
	20	6.343092	8.062439	67.01674	6.859619	1.221223	10.49689	32.98326
ΔlnUK	1	2.338899	1.838288	5.248691	90.57412	0	0	9.42588
	2	3.086815	1.617218	4.608091	80.24929	0.025592	10.413	19.75071
	5	3.313832	1.926747	4.834582	78.87926	0.622853	10.42272	21.12074
	10	3.854882	2.68611	5.695944	76.3835	0.790443	10.58912	23.6165
	20	4.018769	3.453103	5.834605	74.91415	1.147118	10.63226	25.08585
ΔlnGERM	1	1.850985	1.990247	4.153419	32.93277	59.07258	0	40.92742
	2	2.434937	1.70322	3.476798	29.62697	49.45896	13.29911	50.54104
	5	2.802764	2.164385	4.589997	29.22094	48.14802	13.07389	51.85198
	10	3.55084	2.958296	5.080733	28.53212	46.69509	13.18292	53.30491
	20	3.806602	3.478306	5.275818	28.17134	45.90391	13.36402	54.09609
ΔlnUS	1	0.252226	0.944642	0.950764	14.06803	2.316828	81.46751	18.53249
	2	0.400333	0.95954	1.01275	14.84822	2.285144	80.49402	19.50598
	5	0.795151	1.344127	2.454419	14.80083	2.311133	78.29434	21.70566
	10	1.296462	1.477995	2.62433	14.91709	2.349924	77.3342	22.6658
	20	1.710478	2.097052	3.481865	14.85987	3.185158	74.66558	25.33442

close. Thus the values in the first period take account of information revealed in markets operating earlier, and the second day observations show market reactions to information available from foreign markets the day before.

Variance decomposition results are displayed in Table 3. The first thing to note is that no national stock market is independent, in the sense that no market's own innovations fully account for its variance. This is confirmation of the efficient market theory providing evidence that market returns do reflect information impounded in other countries' indices. In addition, studying days one and two can show much about the time structure of the international exchanges. Generally, Hong Kong places great importance on the daily returns from Australia, while Germany is strongly influenced by the UK. At the same time, the UK appears to be the most independent of information occurring prior to its opening, as 90% of its forecast error variance on day one is from itself. The US market, on the other hand, is more strongly influenced by information from previously operating markets as more than 20% of its forecast error variance comes from foreign exchanges. Moving to the second day, though, it is obvious the US dominates the rest of the markets in the sample. Even the UK, which showed the most resistance to foreign influence the period before, is very susceptible to US innovations. This reconfirms the dominance of the US market in the structure of international stock exchanges.

Over the entire 20-day horizon, the most independent markets are Japan and the US. Interestingly, while all markets influence Japan almost equally, the major source of US variance comes from the UK. In contrast, the most vulnerable is Germany, with the majority of the variation coming from the UK. This is probably due to the importance of the UK economy to continental Europe. Australia is the market influenced by the most other international exchanges, as all markets but the US account equally for its variance. There is also some evidence of regional effect. Japan has a moderate influence on Australia and Hong Kong in day one, which erodes after the US market information reaches them in the second day. Meanwhile, Japan is relatively unaffected by the other Asian markets. In Europe, there is a strong influence from the UK to Germany, but there is no feedback from Germany to the UK. Again, note the British Commonwealth effect as the UK is the second most influential exchange for Hong Kong and Australia, and Australia is the second most important to Hong Kong.

Comparing these findings to other studies, the most striking difference is the growing interdependence between the markets now. Using nine markets over the period 1979 to 1985, Eun and Shim (1989) find overall a lower percentage of foreign markets explaining domestic ones. With the increasing globalization over the past 15 years, our finding is not entirely unexpected. Another interesting result reported above is the importance of the UK to Germany, which is in contrast to other papers that found the UK (and France) only barely influence Germany. A possible explanation is the growing power of the European Union and the increased inter-linkage this has created between the Great Britain and continental Europe. Another difference is our finding that foreign markets now account for more of the variance across all horizons. An implication of this is that the US market has become less independent than reported by Eun and Shim (1989). On the other hand, Japan has become more independent in

the sense that it is influenced by foreign markets less than before, a result that is in contrast with the conclusion reached by Eun and Shim (1989). Interestingly, Japan still has a very weak influence on other non-Asian markets, especially given the size of the Japanese economy and its global importance. This could be due to the period of study, which coincides with a continuing recession in the Japan's economy. Thus it appears that global and regional investors are following the stronger US markets rather than relying on the Japanese markets.

In order to examine the role of the US and Japanese markets further, we estimate impulse response functions and use them to determine the degree of informational efficiency in the current market structure. As in the case of the variance decompositions, the results indicate that the US has a very large positive influence on the other five markets. There is a large spike the day after New York trading ends, which is then transferred throughout the system on day two. This lasts only through the second day, as by day three, most markets are back in equilibrium again. With the exception of Japan, which has a significant correction in day nine, the shock wears out in foreign markets after just two days.

The response to a Japanese shock is similar, although it is not as large or as widespread. It causes a significant positive reaction in most of the markets opening later in the day, with the exception of the US. The next day, Germany and the UK experience a significant negative correction, while the rest of the markets simply float back to equilibrium. As with shocks originating in the US, the effect of innovations to the Japanese market wears out in two days. This is the same conclusion reached by Eun and Shim (1989), indicating that markets have not become any more or less informationally efficient over the last decade and a half. Since markets adjust so rapidly to foreign information, there is little scope for international portfolio diversification in the US or Japan, as any significant shock in these countries is picked up abroad and accounted for by the foreign markets. Also, notice that the magnitude of the foreign markets' response to a Japanese shock is not as large as that to shocks originating in the US. Again, this confirms the leading role of the US market in all regions. Meanwhile, the Asian markets do not respond any more than the rest of the markets to a shock coming from Japan, further indicating that there is no large regional effect here either.

The final set of tests is to examine the impact of the 1997 Asian financial crisis on the structure of the global equity exchanges. This crisis represents the most significant global financial calamity in several years, therefore, it provides a good case study of how the international stock market structure responds to such an event and how the system has changed as a result. This is tested by first splitting the sample into a pre-crisis period from January 3, 1995 to July 1, 1997 and a post-crisis period from July 2, 1997 to December 31, 1999, and re-estimating variance decompositions and impulse response functions for each sub-period.

The most noticeable difference between the pre- and post-crisis variance decomposition results is that the influence of Japan and Hong Kong on the remaining markets in the sample has increased in the post-crisis period.[2] Therefore, it seems that the financial crisis has increased

[2] The results are not reported to conserve space but are available from the authors upon request.

the importance of Asian markets, and the rest of the global exchanges are now placing more weight on information coming from these markets in recognition of the global turmoil they can cause. In addition, the variance decomposition results reveal that both the US and Japan have become less resistant to foreign shocks since the crash. This indicates that the Asian crisis has denuded America's leadership role and has reduced Japan's independence.

The re-estimated impulse response functions for both the pre- and post-crash periods indicate that the response to a US shock does not seem to quicken the adjustment to equilibrium during the post-crash period. Moreover, the magnitude of the foreign reactions is larger in the post-crash period than before the crisis. The change in responses to the Japanese shock is much more dramatic. Prior to the crisis, a shock to Japan led to very small changes in foreign markets and did not even significantly effect the UK. After the crisis, the shock has a very significant effect on the rest of the exchanges, including that of the UK.

Overall, comparison of the before – and after - crisis impulse response functions and variance decompositions reveals that the importance of the Asian markets has increased in the rest of the world due to the Asian financial turmoil. In particular, Japan's role has become more profound, as other exchanges now respond more to information coming from Japan. The crisis has, therefore, served to push the Japanese market into more of a leadership role, a position that it has not enjoyed historically.

V. Conclusion

In this paper, we examined the interaction between international national stock markets using daily data and a VAR model. According to the efficient market theory, in the absence of market imperfections, a stock index reflects all available information including that impounded in any other country's stock index. As global equity exchanges operate at different times over a given 24-hour period, information revealed in an eastern market can influence other markets opening later in the west. Given this, the efficiency of information exchange, and the leaders and followers in the global market structure are examined in the last five years, as well as before and after the 1997 Asian crisis. For the entire period, it is found that the speed of adjustment to equilibrium after a shock is about two days, indicating that markets are highly efficient at processing international information. An implication of this is that there is little scope for international portfolio diversification. In addition, the analysis reveals that the US market is the most important in the system, while, surprisingly, Japan is very independent and does not have much effect on the other markets in the sample. Also, there is evidence of only minimal regional interaction between the markets examined, as no discernible patterns were found between the three Asian markets or the two European ones. Finally, the recent Asian financial crisis has had a dramatic effect, amplifying the importance of the Asian markets to the rest of the global exchanges.❖

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Figure 1

Impulse Response to a Shock Originating in the US

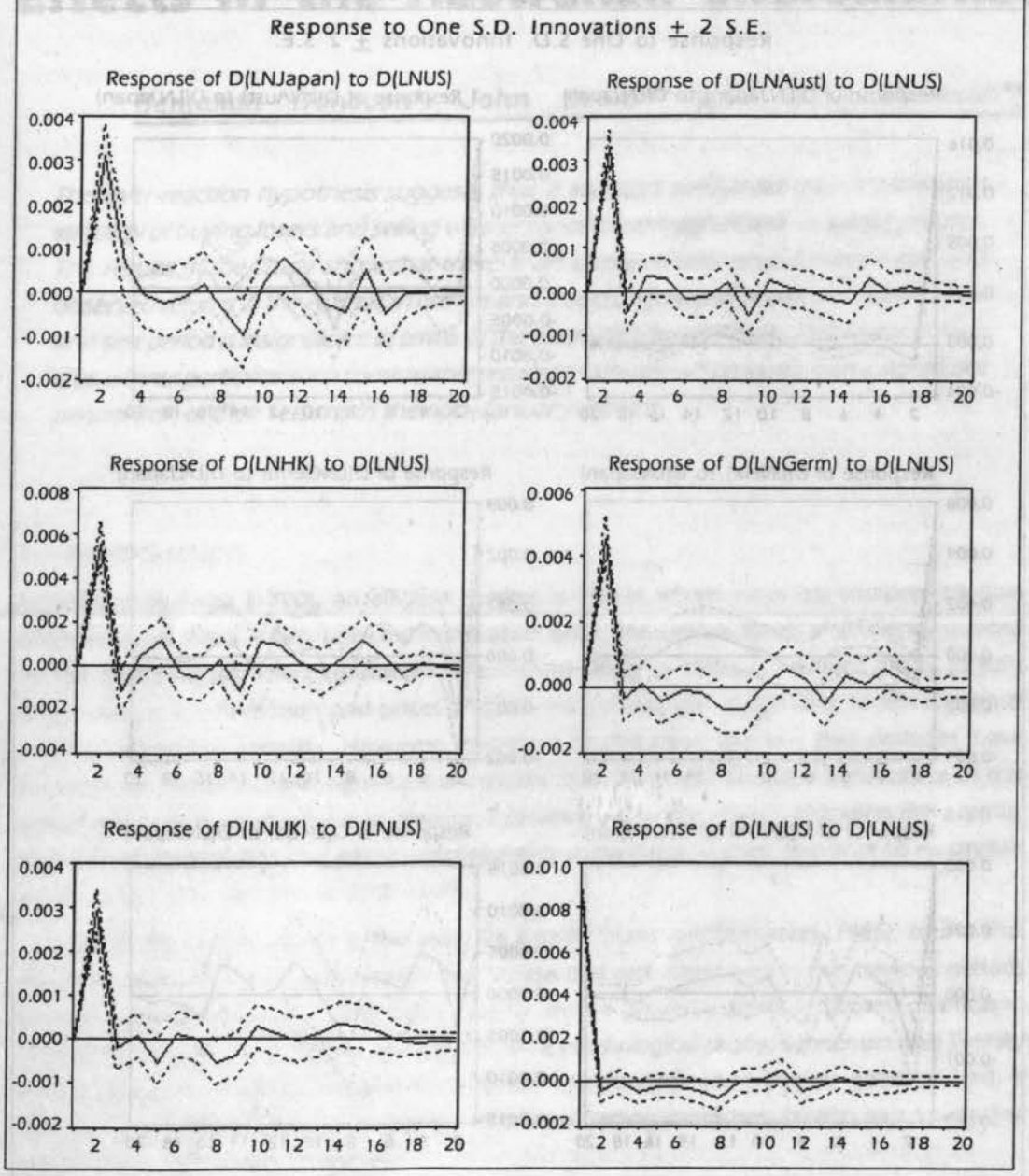

Figure 2

Impulse Responses to a Shock Originating in Japan