High-Frequency Contagion of Currency Crises in Asia*

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Abstract

Using daily data for the period of Asian Currency Crises, this paper examines high-frequency contagious effects among Asian six countries.

In this paper, we distinguishes "origin" (of exchange rate depreciation, or decline in stock prices) and "affected" (currencies, or stock prices) in a sense that the origin is defined as a currency (stock price) whose rate of depreciation over past five days is largest and also exceeds two percent. We find evidence of high-frequency causality: currency crisis appear to pass contagiously from "origin" to "affected".

Then we use various trade link indices to fine that the causality of high-frequency contagion is tied to the international trade channel. There is a positive relationship between trade link indices and the contagion coefficient. This implies that the bilateral trade linkage is an important means of transmitting speculative pressures across international borders.

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1. Introduction

The collapse of Thai Baht's peg on July 2, 1997 has had devastating effects on East Asian countries, even to panic of currency and financial crises in the region. In January 1998, when the crisis was in its most serious period, the cumulative depreciation rate since early July 1997 was about 50 percent for most of the currencies in the region. Among them, Indonesia Rupiah devalued by almost one sixth.

The main interpretations have emerged in the aftermath of the crises. That is, a sudden and a huge capital outflow was one of the key sources of the initial currency crisis. Then it caused a devaluation of currency, soar in interest rate, and clash of stock price to launch a financial crisis. (Corsetti, Pesenti and Roubini (1998a, b), Flood and Marion (1998), Radelet and Sachs (1998), Yoshitomi and Ohno (1999), Ito (1997), Ito (1999), to name a few.) Unlike the typical currency crisis that resulted mainly from the current account and fiscal imbalances as the case of Mexico in 1994-94, the Asian crisis was rooted mainly in financial sector fragilities. This type of currency crisis is followed by Russian crisis and then Brazil crisis in 1998.

In case of the Mexican Peso crash of 1994, several emerging markets fell as investors "ran for cover" because vulnerable countries like Argentina and Brazil were expected to be next in a series of currency crises. IMF support program in March 1995 turned out to be useful to prevent the "tequila effect". The global financial turmoil triggered by Russia's default in 1998 increased risk premium in many emerging markets, but few countries suffered currency crises attributed to Russia's default.[1] The contagion effect to Argentina was also avoided in case of financial crisis of Brazil in 1998-1999.

What was striking in case of Asia was (1) crises to be contemporaneous in time, and

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[1] Short-term interest rate soared from 59% as of June 1998 to 200% as of August 1998. Long Term Capital Management (LTCM) suffered a heavy loss due to a sharp increase in bond spread of developing countries and requested bail out package for the Federal Reserve Bank. In order to avoid further default and liquidity contraction in market, FRB cut interest rates three times during September - November 1998.

(2) unprecedented rapid spread across the region. Within days after the Thai baht floatation in early July 1997, speculators attacked Malaysia, Philippines, and Indonesia. Hong Kong and Korea were attacked somewhat later on. The Asian Crisis differs from other crises in its depth and width of contagion.

In this paper we examine high-frequency contagious effects among Asian six countries (Indonesia, Korea, Malaysia, Philippines, Taiwan and Thailand) for the period of Asian Currency Crises.[2] We use daily data in analysis to capture the day-to-day movements in the financial market and the shift of "first victim" currency (stock price).

We attempt to answer the following questions: Given a large depreciation in the first attacked currency, to which extent the neighboring countries suffer and how fast? Which country is most likely to affect its depreciation to other countries during turbulent times?

Our paper is the first in studying contagious effect that distinguishes "origin" (of exchange rate depreciation, or decline in stock prices) and "affected" (currencies, or stock prices) in a sense that "origin" is the first victim on one day. More specifically, we classify daily depreciation of each country into two groups: a currency that showed the largest depreciation among six currencies as origin and others as affected. In our benchmark regression, we set the origin as explanatory variable. The estimated coefficient in this regression can be interpreted as spillover from a country with the largest depreciation to others. We find evidence of high-frequency causality: currency crisis appear to pass contagiously from "origin" to "affected". In order to see whether our classification of origin and affect reflects empirics, we check country-specific news form Bloomberg of the date we refer to the country as origin.

The structure of the paper is as follows. In section 2, we survey previous studies on

[2] Hong Kong and Singapore are precluded from the survey because (1) Hong Kong adopted Currency board system even after the onset of crisis and therefore continued to peg its currency to the US dollar, and (2) the depreciation of Singaporean dollar was relatively small.

currency crises and contagion. Section 3 summaries exchange rate and stock price of the region during the crisis period. In section 4 we define "origin" and "affected". In section 5 we present empirics and in section 6 we apply time series analysis. In section 7 we study the relationship between high-frequency contagion and trade link channel. Section 8 concludes the paper.

2. Previous Studies on Currency Crises and Contagion

There is a growing literature on the empirical evidence on currency crises and its contagious effects. We have seen at least three important currency crises since 1990s: for example, Collins (1992) and Oker and Pazarbasiouglu (1997) investigate the 1992-93 crises in the European Monetary System. The Tequila crisis is surveyed in Sachs, Tornell and Velasco (1996) and Ito (1997), among others. Corsetti, Pesenti and Roubini (1998a, b), Radelet and Sachs (1998), Baing and Goldfajn (1999), and Berg and Pattillo (1999) investigate the Asian crisis. What we have learned are, in general, two main hypothesis and interpretations of the causes and the spread of crises. According to one view, currency crisis reflects economic conditions in countries—structural and policy distortions, and weak fundamentals. As shown in Kaminsky, Lizondo and Reihnart (1998), some macroeconomic series behave abnormally during periods prior to a crisis. In these cases, it may be necessary to impose strict macroeconomic conditionality on these countries.

Another view focuses on sudden shifts in market expectations and confidence --- caused mainly by investors' panic and herd behavior--- regardless of macroeconomic performance. In a financial market where participants share access to much of the same information, a piece of new information (e.g., an small attack on a currency) can provide a signal that lead to a revision of expectations (an information cascade) in the

market. The market's perception may be interpreted by traders in other markets as an eventual occurrence of a crisis in the near future. This effect could lead to a capital outflow from the market and could result in an attack on currency despite of sound macroeconomic fundamentals. In this case, countries that face difficulties in managing reserves and capitaloutflows should be rescued with financial aid from the international community without any conditionality.

The IMF's new precautionary facility Contingent Credit Lines (CCL), approved by the IMF Executive Board in 1999, was designed to assist countries with strong economic policies and sound financial systems that are seeking to resist contagion from disturbances in global capital markets.

In addition to the crises literature, there is a lot of literature on contagion in currency crises. There is a number of channels through which instability in financial markets might be transmitted across countries.

One channel for contagion is the trade links. The interpretation emphasizing trade links suggests that currency crises will spread contagiously among countries that trade disproportionately with one another. A currency devaluation gives a country a temporary boost in its competitiveness, in the presence of nominal rigidities. Then its trade competitors are at a competitive disadvantage. Deterioration in terms of trade will also worsen competitors' economic performance in the mid- and long- run. Those most-adversely-affected countries are likely to be attacked next. Glick and Rose (1998) find the crisis spread and trade links.

Trade links may not be the only channel of crises transmission, of course. Macroeconomic or financial similarities are not exclusive. A crisis may spread from the initial target to another if the two countries share various economic features. Sachs, Tornell and Velasco (1995) work on contagion in this light.[3]

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[3] Literature based on Macroeconomic fundamentals, see Collins (1992), Flood and Marion

Another approach, "Common Creditor hypothesis" approach is based on the changes in sentiment of investors and lending agencies.[4] When financial institutions face a default in one country, they tend to withdraw capitals not only from the country but also from other countries so that they will avoid further default. Kaminsky and Reinhart (2000) provide related analysis.

It should be noted that the concept of "contagion" varies from author to author.

We can think of a currency crisis as being contagious if it spreads from the initial target, whatever reason.[5] Masson (1999a) argues based on multiple equilibria model that crisis contagion can be referred as equilibrium switch under some economic fundamentals conditions.[6]

The alternative view is that the contagion effect is thought of as an increase in the probability of a speculative attack on the domestic currency. See Eichengree, Rose and Wyplosz (1996), for example.

As is well known, it is difficult to distinguish empirically between common shocks and contagion, especially in phase of crisis. In both explanations above, the actual occurrence (or an increase in likelihood of) crises depend on the existence of a (not necessarily successful) speculative attack elsewhere in the world.

In this paper, we measure the contagion as the ratio of devaluation of currency (decline in stock price) of one country to that of the initially targeted country. Our definition of contagion is in line with two viewpoints above in that it is measured on the

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(1994), Eichengreen, Rose and Wyplosz (1994, 1996), Otker and Pazarbasioglu (1997), to name a few. Kaminsky, Lizondo and Reinhart (1998) is an excellent survey on empirical literatures. Berg and Pattillo (1999) argue the crises predictability.

[4] Agenor and Aizenman (1998) investigate currency crisis based on the imperfect credit market.

[5] Masson (1999 b) classifies the causes of currency crisis into three: (1) common cause (monsoon effect), (2) fundamentals (spillover effect), and (3) trigger of first and hard hit country (sentiment jump).

[6] Flood and Marion (2000) focus currency crisis based on models of multiple equilibria. Jeanne and Masson (2000) apply the Markov Switching model. Obstfeld (1996) incorporates unemployment rate to the multiple equilibria model.

occurrence of crisis.

Our objective in this paper advances these viewpoints to analyze intra-day spillover effect from the first attacked country, namely the high frequency contagion. We do not take a stance on whether the initial attack is by bad fundamentals (first generation model) or is the result of a self-fulfilling attack (second generation model). Instead, we estimate the size of contagious effect from "ground zero", given the incidence of the initial attack. We then find that the high-frequency phenomenon is supportive from trade linkage within Asia.

One of the most significant weaknesses of earlier literatures on contagion is the absence of distinguishing "outset" from "affect" in causality relationship. In financial market, investors are likely to respond to an attack by withdrawing capital not only from the first attacked country, but also from neighboring countries within a few days. In this respect, using monthly or quarterly data, even weekly data, on which many previous analyses based, may restrict to test the existence of correlations among countries during crisis period.

Our measure of contagion is also notable in that we can find systemically important countries, that is, whose contagion effects are significant and sizable. In this paper we focus on the high-frequency contagion in geographic proximity and find evidence that the contagious channel is supported by the bilateral trade. The results are consistent with those of Glick and Rose (1999) and Eichengreen, Wyploz and Rose (1996).

3. Exchange Rate and Stock Price during the crisis period

In the analysis of this paper we use both nominal exchange rate (against US dollar) and stock price daily data of Indonesia, Korea, Malaysia, Philippines, Taiwan and

Thailand.[7] The sample period begins from January 3 1997 for exchange rate and January 3 1994 for stock price and extends up to July 7 1999. Both the exchange rate and stock prices data are obtained from Datastream.

Our analysis is notable in the following respects: (1) data frequency, and (2) definition of origin. First, we use daily data in our analysis. The problem of using low frequency data (semi-annual, quarterly, and monthly) is that it smoothes out a lot of shorter duration interactions between the markets. Low frequency data makes it difficult to capture every small but important event for the sample period. For instance, a large depreciation in Thai baht had a substantial impact on Philippines peso and Indonesia rupiah and then feed back to Thai baht. These feedback movements are, however, diminished by the use of monthly or quarterly data. On the other hand, we should note that it is not always appropriate to analyze with only daily data. It is often observed a large depreciation followed by a large recovery to correct the overshooting. Detailed data construction for regression will be shown in the following section.

Figure 1 (exchange rate, June 30 1997=100)

Figure 1 shows the exchange rates of six currencies against US dollar from June 30 1997 to July 7 1999. They are normalized at 100 on June 30 1997. The behavior of exchange rates through the crisis period varied considerably across the countries. In Thailand, after an initial sharp depreciation (due to the floatation of baht) in July 1997, there were a series of smaller, but still substantial depreciation over a prolonged period, culminating in 16-17 percent depreciations at the end of August. The pressures were eased in September in response to measures to prevent further depreciation and a

[7] Stock price indices are: Jakarta Composite Index (ID), Korea South Composite Index (KR), Composite Index (ML), Composite Index (PH), Weighted Index (TW), Bangkok Book Club (TH).

deterioration of economic activity. The exchange rate finally bottomed out in early 1998.

In contrast, Indonesia's exchange rate depreciated fairly steadily starting in July 1997. Pressure on the Indonesia rupiah intensified in late September in view of increasing strains in the financial and political sector. With the rupiah falling further against the U.S. dollar, by early October, IMF-supported programs for Indonesia were announced on October 31, 1997.[8] Then, Indonesia rupiah recovered temporarily in response to the program. The limited recovery in the next few months was reversed by large further depreciation starting in late 1997 to mid 1998.

Korea avoided substantial depreciation until October 1997, with the exchange rate remaining broadly stable through July-October 1997. However, as Korean banks began to face difficulties related to their short-term foreign liabilities, the exchange rate fell precipitously during late November 1997-January 1998.

Figure 2, stock prices

Figure 2 plots stock price indices of 6 countries from January 3 1994 to July 7 1999, with January 3, 1994=100. Stock market paints a different picture from exchange rate market. Stock price of Thailand was at its peak in early 1990s. On the other hand, stock prices of Indonesia, Korea, Malaysia, Taiwan continued to increase/ or had been stable until late 1996.

Stock prices of Korea, Malaysia and Philippines began to fall in December 1996. In Indonesia, stock prices increased through mid-1997, but fell sharply in the aftermath of the Thai crisis. Stock prices of Taiwan also fell by some extent, but its level still exceeds the 1994 price level. In October 1997, stock prices of Korea and Malaysia dropped

[8] On November 5, 1997, the IMF's Executive Board and Indonesia approved a three-year Stand-By Arrangement equivalent to $10 billion. Additional financing commitments included $8 billion form the World Bank and the Asian Development Bank, and pledges from interested countries amounting to some $18 billion as a second line of defense.

significantly.[9] The declines in stock prices continued until September 1998, then headed for recovery except Thailand and Malaysia.

4. Definitions of "origin" and "affected"

In this paper, we try to statistically analyze the size of contagion. Our basic regression is :

Affected=const + a*Origin + e,

where Affected is a measure of change in exchange rate (stock price) of country i, and Origin is that of first attacked country. We estimate this equation using Dynamic OLS across countries.

We first construct an indicator that distinguishes "origin" from others that are referred to as "affected". To sketch our idea briefly, we first show the weekly (Friday to Friday) origin. It is calculated based on the weekly change in exchange rate. Weekly origin is a currency that depreciated most in a week and, on top of that, whose depreciation rate exceeds 4%. This cut off value is arbitral.

Table1-1 plots weekly origin of exchange rate depreciation. Sample period is from July 1997 to January 1998.

Table 1-1、weekly origin

One problem using weekly change as origin is that weekly origin depends on the choice of the day of the week. Think of a currency that depreciates 3 percent from Thursday to Friday and then again 2 percent from Friday to Monday. Using the definition of 4 percent depreciation starting on Friday does not pick this currency as

[9] In October 1997, Hong Kong dollar was targeted of speculative attack and the Currency Board system raised interest rate that resulted in a decline in stock prices. So, several measures to shore up the stock market, including public funds injection, were taken.

origin; while, Monday-to-Monday origin does.

Now we proceed further to determine daily origin of exchange rate (stock price). The daily origin is derived based on weighted change of exchange rate (stock price) for previous 5 working days. The advantage of this daily origin is that it is not sensitive to the choice of the day of the week.

First, daily percentage change of the exchange rate is written as:

$$DR(t,j) = R(t, j) - R(t-1, j),$$

where R(t,j) is log of nominal exchange rate (country j) with respect to the US dollar at date t. We next compute weighted average cumulative change, DRR(t,j), as follows:

$$DRR(t,j) = 0.5DR(t,j)+0.25DR(t-1,j)+0.125DR(t-2,j) +0.0625DR(t-3,j)+0.0625DR(t-4,j).$$

The DRR is derived based on the declining weight of DRs.[10]

The rationale for our measurement of origin based on DRR, not on DR is as follow; It is often observed a large recovery of exchange rate (stock price) following a day with large depreciation. For example, both currency A and B were heavily hit to depreciate 11 and 10 percent respectively. Next day, currency A showed a recovery of 8 percent, while currency B did only 2 percent. It would be appropriate to interpret that currency B was more severely targeted. DR-based-origin, however, counts A as ground zero. We are likely to misjudge the severity of crisis should we see only the daily percentage of

[10] The weights are arbitral and 0.25 for lag 1, 0.125 for lag 2, 0.0625 for lag 3 and 4. The optimal weight (coefficient) may be computed from running VAR, but this method would not be plausible for East Asian countries since they pegged their currencies to US dollar prior to 1997.

depreciation.

Our declining weight scheme is intended to avoid effect of large changes of days ago. We do not think of a crisis as "severe" even if the rate of depreciation (decline in stock price) is large but one-time-only. Assume even weights in calculation. A very large depreciation 5 days ago might affect determination of the current origin. But it turns out that the currency does not appear as origin the following day when the large one-time depreciation days ago is excluded from the calculation. There is a possibility that a large change in exchange rate (stock price) days ago might lead a currently non-volatile currency as "origin" if we use even weight in calculation. Imposing declining weight avoids this misspecification.

Our origin measure is defined analogous to our DRR as;

DOR(t,0) = "origin" = the largest DRR at each t and whose depreciation rate also exceeds 2%.[11]

Table1-2 and Table 1-3 summarize the DOR(t,0) of exchange rate and stock price, respectively.

Table 1-2, Daily origin(exchange rate), Table 1-3 （Stock price）.

Table 1-2 lists our measure of origin of exchange rate depreciation from July 1997 to July 1999. The table makes it straightforward to pin down the attacked date in each country. For instance, July 1997 for Thailand, August-September for Indonesia, October 1997- January 1998 for Korea, and after January 1998 for Indonesia. With the economy back on the growth path after April 1999 in most of Asian countries, the number of plots of origin declined. Our measure of origin is consistent with journalistic and academic references as to the beginning of the crisis period; number of different

[11] The threshold of 2% is arbitral.

measures gives a starting date of July 1997 for Thailand, August 1997 for Indonesia, and November 1997 for Korea.

Table 1-3 plots the origin of stock price decline. The stock in the region was at its peak in early 1990s and then head off downward in most of countries. The rate of stock price decline often exceeded 2 percent in early 1994. Since late 1996, stock prices began to fall in Thailand and fell by almost one third. The decline continued in Thailand in early 1997. In Indonesia, stock prices increased through mid-1997, but fell dramatically in the aftermath of the Thai crisis. The abruptly slipping exchange rates, together with tremors in the financial and economic activities, culminated in a financial (stock) market crisis that led to the decline in the stock prices in the region. In Korea, the decline of stock price was temporarily interrupted in the first half of the year but continued in the second half in the wake of banking sector crisis. As the contagion of exchange rate depreciation spread in the region, the downward pressure of stock prices was further intensified in Malaysia, Korea, and Indonesia. Since July 1998, stock price decline originated mainly from Indonesia, Malaysia and Philippines. The rate of decline and the frequency of large decline have been moderated since December 1998.

In wake of crisis, market sentiment is likely to be more volatile. Investors respond to news and events that cover market fragilities and deteriorating economies of attacked and expected-target countries. The news works as a signal to investors. In this respect, the eruption of a signal provides investors sufficient and supportive information that an attack would be successful; then they will concentrate their attacks on currencies (stock price) that are expected to depreciate to very low.

Table 2 lists news release from Bloomberg. Every news release corresponds to the timing and date of origin in Table 1-1 and Table 1-2, respectively.

Table2, exchange rate, daily origin-News

The table shows the news release of origin countries. For early stage of crisis, news was relatively straightforward and was categorized to crisis-related statement; such as authorities' announcement on exchange rate regime, foreign reserves and IMF support package.

In late 1997 and early 1998, news was rather related to the vulnerability of financial and economic systems, bankruptcies and political instability. A case can be seen that concerns on banking systems in Korea intensified the devaluation pressure at this stage. It is also argued that exchange rate movement was highly sensitive to political instability in Indonesia.

5. Matrices of Cumulative Contagion

In order to make our ideas of high-frequency contagion more concrete, we provide a new indicator of contagion: contagion coefficient. This is the ratio of depreciation rate of origin to that of affected country. This contagion coefficient measures high-frequently spreading of financial crisis (depreciation, or decline in stock prices) from origin (first attacked country) across other affected countries.

The contagion coefficient is calculated as:

$$CC(t,i) = DRR(t,i) / DOR(t,0),$$

where $i \neq 0$. Table 3-1 reports CC(t,i) for exchange rate and Table 3-2 to Table 3-4 report CC(t,i) for stock price. Sample period starts July 1 1997 and ends July 7 1999.[12]

[12] The sample period includes when Malaysia began to peg its currency to US dollar starting at September 1, 1998. The daily percentage change in exchange rate is close to zero and so is the DRR in Malaysia after September 1998. Therefore, Malaysia is virtually excluded from "origin" for this period. Thus, we do not need to explicitly impose structural change on Malaysia when we run regressions in the following section.

Negative sign of CC indicates the opposite movements of exchange rate (stock price) between origin and affected countries. In the case of exchange rate, devaluation of origin country leads to appreciation of affected countries. On the other hand, positive sign of CC indicates that the direction of exchange rate (stock price) movements between Origin country and affected countries are the same. That is, devaluation of origin country leads to a devaluation of affected countries: contagion.

Table3-1 plot of CC (exchange rate), 3-2～3-5 (stock price)

Table 3-1 shows CC(t,i) for exchange rate. As shown in Table 1-2, frequency of origin drastically decreases since June 1998. Exchange rates had been back on recovery track by the summer 1998. Most of crisis (large depreciation) after July 1998 were from Indonesia. Therefore, we divide sub-sample period into two in the case of Indonesia.[13] Specifically, for origin of Indonesia, we calculate CC(t,i) for two sub-sample periods, crisis period (1997/7/1-1998/6/17) and recovery period (1998/6/18-1999/7/7), in addition to whole sample period (1997/7/1-1999/7/7).

In the case of exchange rate, there are 87 instances that are regarded as origin in terms of our definition. Out of them, 61 instances are of Indonesia, 14 instances of Korea and 6 instances of Thailand.

Stat (statistics) in Table 3-1-Table 3-4 tests the null of zero.[14] The null measures insignificant difference of the rate of depreciation (decline) between origin and affect countries: that is, there exists no significant high-frequency contagion from origin to affected.

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[13] After June 1998, most of currencies in East Asia went back on the recovery track, while Indonesia rupiah was trending down. So, the sign of CCs on Indonesia at this period is likely to be negative.

[14] Calculation is as follows: Stat = (x^-x0)/(square root of variance / square root of NOB), where x^:average; x0:(Null)=0 and x0 is the ratio of DOR/DRR (CC).

The significance of estimated coefficients varies according to sample periods and countries. The coefficients of contagion originating from Thailand and from Philippines are, in many cases, negative. Shortly after the onset of currency crisis when Thai baht and Philippines peso, two first-hard-hit currencies, devalued, other currencies were not severely hit and remained their value to US dollar. The contagion coefficients of them are, however, not significantly different from zero.

The sign of coefficients of affected countries, a case for either Indonesia or Korea is origin, are positive and significantly different from zero: depreciation of Indonesia and of Korea induces high-frequency contagion effect. That is, we find evidence of significant high-frequency contagion originating from Indonesia to Malaysia, Indonesia to Thailand, Korea to Malaysia, Korea to Thailand and Korea to Indonesia.

The contagion coefficients originating from Indonesia are positive and significant in all but Korea over the sample period up to June 17, 1998. After June 17, 1998, the results reverse: the contagion coefficient is significantly positive only in Korea and insignificantly different from zero or significantly negative in other countries.

In sum, depreciation of Indonesia and of Korea has significant high-frequency contagion effect on other currencies but not vice versa.

Table 3-2 - Table 3-4 presents CC(t,i) of stock prices. Table3-2 shows CC for whole sample period; Table3-3 and Table3-4 report pre-crisis and post crisis period, respectively.

For Indonesia, there are 2 instances to be origin for pre-crisis period and 28 instances for post-crisis period. For Korea, 3 instances for pre-crisis and 44 for post-crisis; for Malaysia, 4 for pre-crisis and 25 for post-crisis. In these 3 countries, number of instances regarded as origin dramatically increased after the onset of crisis.

On the other hand, for Philippines and for Thailand, the instances do not make a big change. For Philippines, there are 12 instances for pre-crisis period and 15 instances

for post- crisis period. For Thailand, 17 for pre-crisis and 16 for post-crisis. For Taiwan, in contrast to other countries, the instances surprisingly decreased from 16 for pre-crisis period to 6 for post-crisis period. The instances as origin as a whole dramatically increase for post-crisis.

Contagion coefficients of ASEAN countries for the post-crisis period turn to be significantly positive, or the magnitude of contagion coefficients become larger. A case for Korea to be origin,, contagion coefficients for pre-crisis period are negative, while they become positive and significantly different from zero for post-crisis period.

In sum, we may conclude that high frequency contagion of stock prices has been intensified through currency crises period.

6. Regression

In the previous section we find high-frequency contagion in both exchange rates and stock prices among Asian countries. We also note that the stock price high-frequency contagion becomes intensified after the crisis.

In this section, we present some formal econometric results to statistically show to what extent the depreciation of exchange rate (decline of stock prices) of first attacked country, namely origin, affects others.

The regressions are estimated using Dynamic OLS (DOLS) method in the following specification:

$$\text{affected}(t,i) = \text{const} + a1*\text{origin}(t, 0) + b1*\text{dorigin}(t+1, 0) + b2*\text{dorigin}(t, 0) + b3*\text{dorigin}(t-1, 0) + e,$$

where $i \neq 0$. Here, affect(t,i) is DRR, origin(t,0) is DOR defined in section 4 above, and dorigin(t,0) = DOR(t,0)-DOR(t-1,0). DOLS method provides efficient estimator if the

regressor is cointegrated or endogenous. By including the current change as well as the past and future changes of regressor in the regression, we are able to maintain the strict exogeneity of the regressor, the origin (DOR). The order of leads and lags of changes of regressor is arbitral; we set 1 in the analysis below. Standard error for point estimate of *a1* is recalculated based on the DOLS residuals and then adjusted to the sample period of recalculated augmented cointegrating regression.[15]

For purposes of comparison, 2 types of estimation are done: (1) the regressor, origin(t,j), includes every "origin". That is, we do not distinguish the first attacked "country". We call this regressor "pooled origin". And, (2) country specific origin(t,j). That is, we run regression on origin according to country. We call this "country-specific origin".

The expected sign of point estimate of a1 is positive if there exists high-frequency contagion. Estimation results are summarized in Table 4-1 and Table 5-1～ Table 5-8.

Table4-1 exchange rate, DOLS

Table 4-1 shows the estimates for exchange rate. Sample period covers from July 1 1997 to July 7 1999. The dependent variables are "affected" countries and independent is "origin". The first row of the table shows the regression results on pooled origin. The second and the third rows of the table show the estimation results with country-specific origin of Indonesia and Korea, respectively.[16]

Estimation results show that estimated coefficients in Korea, Malaysia, Philippines and Thailand on pooled origin are positive and significantly different from zero. The sign of estimated coefficient is, however, negative in Indonesia. The result for Indonesia can be interpreted as that the behavior of Indonesian rupiah is slightly different from others.

[15] See Hayashi (2000) for details.
[16] DOLS regressions include leads and lags in both OLS and residual regressions and therefore, reduce degree of freedom. Thus, Thai origin is precluded from the regression.

For example, most of the currencies in East Asia are back on recovery track around April 1998, while Indonesia rupiah has been trending down.

Estimated coefficients in Korea, Malaysia and Philippines are significantly different from zero and range from 0.12 to 0.19. In contrast, estimated coefficient is not significant in Taiwan; that is, the high-frequency contagion is not significantly seen in Taiwan. This finding is consistent with the fact that Taiwan is one of the least hit and the least contagious suffered countries in 1997.

Now we see estimation results on country-specific origin. A case for Indonesia as origin, contagion coefficients in Philippines and Taiwan are significant. Contagion coefficients in Malaysian and Thailand are small but significantly different from zero. In contrast, contagion coefficient in Korea is significantly negative. Indoneisa rupiah severely depreciated following the Korea won in early 1998. The movement of Korean won might be opposite to that of Indonesia: when Indonesia was hard hit, Korean won was on the recovery track. Therefore, the coefficient of Korea on rupiah is likely to be negative.

There seems a significant high frequency contagion in Indonesia and Malaysia in case of Korea origin. The estimated coefficient in Indonesia is 0.68 and significantly different from zero. The estimated coefficient in Philippines is 0.24 but is not insignificant. The estimated coefficient in Thailand, however, is significantly negative.

We find two important messages from Table 4-1. First, there exists high-frequency contagion among East Asian countries. Our contagion coefficients of affected countries are positive and statistically significant in most countries. Second, estimation results on country-specific origin show that contagion effects from Indonesia and from Korea are significant in some countries.[17]

[17] Baig and Goldfajin (1999), for instance, use VAR to analyze impulse response among Indonesia, Korea, Malaysia, Philippines and Thailand and conclude that the impulse shock of Indonesia has significant effect on other countries. Our findings are consistent with these results.

Table5-1～Table5-7 Stock Price DOLS

Table 5-1-Table 5-7 presents the estimate results for stock prices. We run regressions for three sample periods: whole sample period (January 1994-July 1999), pre-crisis (January 1994-June 1997), and post-crisis period (July 1997-July 1999). Due to the degree of freedom, regressions for pre-crisis period for either Indonesia, Korea or Malaysia to be origin are excluded. The regression estimates on origin in the case of Taiwan is not shown for post-crisis period.

Estimates results of contagion coefficients on pooled origin are shown in Table 5-1. Contagion effects are significant in all countries for the whole sample period. The estimated coefficient is significantly negative in Korea for both pre- and post- crisis periods. However, the magnitude of coefficient becomes smaller for post crisis period.

The magnitude of estimated coefficient in Taiwan, on the other hand, declined sharply after the crisis. Taiwan was less influenced from high-frequency contagion.

Table 5-2 to 5-7 presents estimates results on country-specific origin.

Table5-2 shows the estimates results on Indonesia origin. The estimated coefficients are significantly positive in both Malaysia and Philippines.

Table5-3 is the case of Korea as origin. All estimated coefficients, except Thailand, are significantly negative. The magnitude of estimated coefficients for post-crisis period becomes larger (in negative) in Indonesia and Malaysia. These are consistent with the fact that Korean stock price index declined sharply in late 1997 while stock prices in other countries remained stable.

Table5-4 reports results on Malaysia origin. Estimated coefficient is significantly positive only in Thailand. Most of the estimates are significantly negative.

The results of Philippines origin are summarized in Table 5-5. The estimated coefficients in Indonesia, Korea and Malaysia are significantly positive for both pre- and post- crisis periods. Sign of coefficient turns to be positive (but insignificant) in Thailand