How Much Does Trade and Financial Contagion Contribute to Currency Crises? the Case of Korea

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Abstract

The prime task of modelling cross-market contagion is to predict the imminence of a pestilent currency crisis. Empirical models are developed here to study the roles and channels of contagion in exchange rate volatilities, in ways which are as economically sound and econometrically simple as possible. Korea is used as the susceptible and eight adjacent economies as the potential infective. Two channels of contagion are investigated – trade linkage and financial market linkage. Two key features of the latter channel are carefully specified – the changing degrees of infectiveness of a neighbouring economy due to its changing capital mobility, and the changing intensity of currency speculation in response to the changing vulnerability of the susceptible. By using monthly data prior to the 1997 Korean won crisis, the models predict a looming currency collapse. Since the respective roles of major internal and external factors which propagate shocks to the won rate are carefully identified in the models, it is thus manifest that contagion indeed played a major role in the won collapse, that financial contagion was the main culprit whereas trade contagion played only a minor part, and that the susceptible is especially prone to shocks from economies which are structurally similar to or weaker than it.

JEL classification: D50, E22, E44, F31, F34, F41, G20, O16, O23, O53

Key words: currency crisis, trade contagion, financial contagion, infective, susceptible, capital mobility, international financial market, herding, heterogeneous trading, currency speculation, discrete-state regression

1 Introduction

Cross-market contagion of currency crises has become one of the most popular and active research topics in the wake of the 1997 East Asian financial turmoil and the 1998 Russia's default. Two major infective channels are widely discussed: spillover via international trade and contagion via international capital markets, e.g. see (Frantzscher 1998), (Masson 1998), (Forbes and Rigobon 1999a; 1999b), (Kaminsky and Reinhart 1999a), (Dornbusch and Park 2000) and (Pritsker 2000).[1] The latter channel, in particular, has attracted the focal attention.

The present study endeavors to identify empirically how much the two channels of contagion could contribute to a currency crisis, using Korea as the guinea pig (see graph 1 for the won collapse). This paper can be seen as a sequel to (Qin 1999), in which the contribution of Korea's excess debt problems to the won fluctuations was modelled. That modelling experiment shows that the Korean won crisis was not triggered by excess debt problems, albeit the debt problems have been positively propagating exchange rate fluctuations. It is therefore natural to raise the current question of how much we could identify the contribution of external contagion.

Empirical models of the transmission channels of contagion are still at an infant stage. Several approaches have been experimented, see (Forbes and Rigobon 1999b). For instance, cross-market contagion is identified and estimated by correlations between the error terms of models of the VAR (vector autoregression) type, e.g. see (Baig and Goldfajn 1998), (Gelos and Sahay

[1] Notice however there are no agreed definitions or classifications of "contagion" in the literature (see the cited papers). Here, we do not want to get involved into these discussions and just simply adopt the broad sense of the term, i.e. contagion due to infection by external shocks and crises.

1999), (Kaminsky and Reinhart 1999b) and (Park and Song 2000); A much more popular approach is to construct certain composite indices of crises, and explain these indices by certain variables representing trade spillover and financial contagion in the form of binary choice models, such as probit or logit models, e.g. see (Esquivel and Larraín 1998), (Gregorio and Valdés 1999) and (Van Rijckeghem and Weder 1999). The latter approach gives a much clearer representation of the possibly contagious factors than the former one, since the error terms of regression models are, in fact, neither autonomous nor free of potential specification errors, see (Qin and Gilbert 2000). However, the latter approach suffers from three drawbacks here. First, most of the volatility information in the raw data is filtered out by the definition of a discrete no-crises versus crises (i.e. 0/1) series, thus virtually softening the task of explaining crises. Secondly, different dynamics of individual variables, such as exchange rates and short-term interest rates, are arbitrarily mixed in the constructed composite crisis indices, thus making it difficult to explain them by proper structural or behavioural relationships. Moreover, since crises are very rare in one economy within a certain time period, models of this type have to rely on merging data from different economies over different time periods, thus losing the capacity of delving into country-specific characteristics. These weaknesses are the most manifest in the poor out-of-sample prediction performance, see (Berg and Pattillo 1999).

The methodology adopted here is to explain the volatilities of exchange rate returns in error-correction models (ECM) following the dynamic specification approach, see (Hendry 1995). The main advantages of this approach merit brief attention. Primarily, it enables us to decompose the explained variable, i.e. the exchange rate returns, into a number of relatively orthogonal shocks, such long-run disequilibrium errors, self-feedback adjustments and various short-run propagating shocks, in addition to an unaccountable residual term. It thus could be viewed as a structural extension of a VAR model in a single-equation context, or as an encompassment of the approaches reviewed in (Forbes and Rigobon 1999b). Here, the decomposition is especially powerful in that it allows us to be focused on experimenting with various possible channels of contagion in the form of short-run propagating shock variables. More importantly, we could evaluate the predictive power of these individual shock variables by leaving the data sub-period covering the crises out of model estimation. In other words, the degrees of trade versus financial contagion are assessed ultimately by their roles in the out-of-sample prediction of the crises. This amounts to assuming no "structural breaks", or parameter constancy, of the model during the crisis period,[2] an assumption which entails a high degree of robustness to be achieved during model specification.

Specifically, the current study begins to model contagion on the basis of a monthly ECM of the won rates, reported in (Qin 1999), extended with an intrinsic bubble or self-fulfilling effect and an ARCH effect, and estimated by the ML (maximum likelihood) method (sample: 1980M1 to 1997M9):

[2] There are confusing views on how to represent the transmitting mechanism of crises in the recent literature. In particular, the phenomenon of intensified cross-market correlations during crises, see e.g. (Baig and Goldfajn 1998), leads to the belief that the phenomenon should be captured in models by regime shifts or structural breaks between the tranquil period and the crisis period. This, however, can be a *non sequitur* belief because it is perfectly possible to represent in models the changing correlations as certain shock propagating variables with invariant transmitting ceofficients. The present study opts to explore this possibility because the regime shift representation would deprive an empirical model of its prediction power at the time when it is the most needed.

$$
\begin{aligned}
\Delta r_t = \; & \underset{(.002)}{0.145} - \underset{(.01445)}{0.086} \left[\ln(\tfrac{P_h}{P_f})_{t-1} - 0.01 Id_{t-2} - 0.089 sf_{t-1}\right] \\
& - \underset{(.0429)}{0.118}\, \Delta r_{t-1} + \underset{(.1297)}{0.6252}\, \Delta \ln(\tfrac{P_h}{P_f})_t \\
& + \underset{(.01537)}{0.1352}\, \Delta_3 sf_{t-1} + \underset{(.0001466)}{0.0009}\, \Delta_3 |sf|_{t-1}^{\overset{5.449}{(.0172)}} + \underset{(.013)}{\widehat{\nu}_t}, \\
& \sigma^2_{\nu_t} = 0.0001 + \underset{(.1382)}{0.5245}\, \widehat{\nu}^2_{t-j}
\end{aligned} \tag{1}
$$

where $\Delta r_t = \ln(R_t - R_{t-1})$ denotes the nominal exchange rate returns of the Korean won, P_h and P_f the domestic and foreign price levels respectively, $Id = I_h - I_f$ the interest parity, and sf_t the logarithm of the share of foreign liabilities in the total commercial bank loans. Figures in brackets underneath the coefficient estimates are standard deviations, see (Qin 1999) for more details of the model.

Monthly data is the highest possible frequency with respect to the selected variable set in (1). Since there was a lag of several months between the Thai baht crisis and the Korean won crisis, it should be possible to study whether the former has initiated any contagious impact on the latter using monthly data. It turns out, in fact, that positive results have been reported in several other studies using monthly data, e.g. see (Gregorio and Valdés 1999) and (Park and Song 2000).

To capture the regional effect, we define the relevant external region of Korea as made of eight economies, namely, Hong Kong (HK), Indonesia (IND), Japan (JP), Malaysia (MAL), the Philippines (PH), Singapore (SGP), Taiwan (TW) and lastly Thailand (TAI), the origin, or the so-called "ground-zero" country, of the 1997 Asian financial crisis. The choice of these eight economies is somewhat arbitrary, though it coincides largely with a number of other studies, e.g. (Park and Song 2000). Apart from consideration of regional trade links, the choice is bound by data availability, for example, China is excluded due to inadequate length of data series. Nevertheless, much of the trade with Hong Kong relates to China. Graph 2 illustrates the exchange rate returns of these economies. The present data set covers the period of 1986-1998, in which the last 15 months, i.e. 1997M10-1998M12, are reserved for out-of-sample forecasts.[3]

The rest of the paper is organised as follows. The next section investigates contagion caused by spillover of currency crises via the trade linkage. Section 3 looks at financial contagion via the capital market linkage. Section 4 extends the base model with the findings of sections 2 and 3. The main implications of the modelling experiment are summarised in the concluding section.

2 Spillover via Trade Linkage

Let us first examine the possible transmitting channels of currency shocks via Korea's trade with the eight adjacent economies. Exports to these economies has taken up about 30% of Korea's total exports during the 1990s. Two types of trade links are commonly identified in the literature. One is the direct link via bilateral trade and the other is the indirect link via competition in a common third market, e.g. see (Kaminsky and Reinhart 1999a) and (Gelos and Sahay 1999). Here, we choose to specify only the direct trade link for lack of data. However, the indirect link can be partly reflected in the correlations between the trade variables of these eight economies. In particular, a simple trade shock variable st_{jt}, for each adjacent economy j, is defined as the product of the nominal exchange rate returns Δr_{jt} and a

[3] Notice that the current sample period is shorter than that used in the estimation of the base model (1) due to data unavailability.

trade weight wt_{jt} of that economy with respect to Korea:

$$st_{jt} = wt_{jt} \times \Delta r_{jt} \qquad j = \text{HK, IND, JP, MAL, PH, SGP, TW, TAI} \tag{2}$$

where the series wt_{jt} is taken as the share of Korea's exports to economy j in the total Korean exports.[4] The eight st_{jt} series thus calculated are plotted in graph 3. Table 1 gives the means, the standard deviations and the correlation coefficients of these st_{jt}. Notice that only Hong Kong shares negative correlation coefficients with several other economies, suggesting it being the major competitive market of the region.

Since Korea is the susceptible economy here, we choose to use simple distributed-lags models. This choice amounts to assuming that all external trade shocks are strongly exogenous. The assumption is confirmed partially by the Granger non-causality test results reported in table 2 and partially by the results of (3) and (4), in which none of the trade shocks is found to exert significant contemporaneous impact, except for Singapore.

Specifically, two distributed-lags models with 3 lags are estimated, one using Δr_t and the other $\widehat{\nu}_t$ of equation (1) as the explained variable:

$$\Delta r_t = \sum_{i=0}^{3} \sum_{j=1}^{8} \delta_{ij} st_{j,t-i} + \epsilon_t$$

and

$$\widehat{\nu}_t = \sum_{i=0}^{3} \sum_{j=1}^{8} \delta^*_{ij} st_{j,t-i} + \epsilon^*_t$$

The use of $\widehat{\nu}_t$ as an explained variable requires orthogonality of all the ex-

[4] More elaborate trade weights are proposed by Fratzscher (1998) and Glick and Rose (1998). We have chosen the simpler weights wt_{jt} mainly because we do not considerate bilateral spillover via trade here.

planatory variables in (1) with the newly introduced trade shock variables st_{jt}. We shall check this condition in Section 4.

Reducing the models via OLS estimation by the general→specific approach, we get:

$$\begin{aligned}\Delta r_t = & \underset{(.0271)}{0.1069}\, st_{SGP,t} + \underset{(.0402)}{0.1109}\, st_{PH,t-1} + \underset{(.1038)}{0.2309}\, st_{TAI,t-3} \\ & - \underset{(.0363)}{0.068}\, \Delta st_{MAL,t} - \underset{(.107)}{0.2204}\, st_{HK,t-3} + \underset{(.0119)}{\widehat{\epsilon_t}}\end{aligned} \tag{3}$$

and

$$\begin{aligned}\widehat{\nu}_t = & \underset{(.0218)}{0.07}\, st_{SGP,t} - \underset{(.0351)}{0.0731}\, st_{PH,t-2} \\ & + \underset{(.0292)}{0.0953}\, st_{MAL,t-1} - \underset{(.0903)}{0.1632}\, st_{HK,t-1} + \underset{(.0105)}{\widehat{\epsilon_t^*}}\end{aligned} \tag{4}$$

Diagnostic tests of these two regressions are presented in table 3. Graph 4 shows the forecast results.

It is evident from graph 4 that trade contagion did not play a major role in triggering the 1997 won crisis, a result in confirmation with what has been generally believed in the literature, see e.g. (Baig and Goldfajn 1998) and (Gelos and Sahay 1999). Nevertheless, currency shocks via trade linkage from both Thailand and the Philippines, two of the leading infective economies of the 1997 Asian financial crisis, are found to exert positive feedback on Δr_t in (3). Meanwhile, the negative impact played by Hong Kong shows that it forms a major competitive trade market with Korea. Moreover, (4) shows that spillover via trade helps to further explain part of what the domestic factors, in terms of explanatory variables in (1), cannot explain of the volatilities in the won rates. Here, it is also interesting to note in table 3 that the trade shocks have explained away the residual ARCH effect found in (1).

3 Contagion via Capital Market Linkage

It is more difficult to model contagion via the international capital market than via the trade linkage, because of three main reasons. First, the eight neighbouring economies carry different degrees of risk from each other, due to their differences in capital market structures and particularly in their different levels of exposure to the international financial markets, or their different degrees of capital control. Moreover, these degrees of risk must have changed considerably as a result of various policy shifts in financial market regulations experienced by these Asian economies over the last decade. Secondly, for similar reasons, Korea has also experienced changing degrees of susceptibility to financial contagion. Thirdly and most importantly, financial crisis in one economy may trigger, in international financial markets, sudden shifts of investors' sentiment and heavy speculative activities towards other adjacent economies so that the susceptible would suddenly find themselves in much more vulnerable positions than expected.

To tackle the first issue, we construct a measure for the infective risk by the level of international capital mobility of an economy. Two approaches are commonly used in the literature to define international capital mobility. One is based on the balance of payment framework, e.g. the Feldstein-Horioka definition (1980).[5] The other is based on the capital asset pricing principle, e.g. see (Frankel 1991). From the macroeconomic perspective, the Feldstein-Horioka definition appears quite attractive, and could be easily extended to a time series by taking the ratios of the domestic investment rates to the

[5] In essence, the Feldstein-Horioka definition uses the correlation between domestic investment and saving rates as a measure of capital immobility, and the correlation can be measured both cross-sectionally for a number of economies and over time for a single economy, see also (Feldstein and Basshetta 1991) and (Artis and Bayoumi 1991).

domestic saving rates. In fact, the institutional variable of wealth-debt ratio used in (Qin 1999) coincides very much with this idea. However, there are two drawbacks in this approach. Theoretically, the validity of the Feldstein-Horioka condition is dependent upon a number of assumptions which are not easily verifiable in practice, as Frankel (1991) points out. Empirically, official statistics relating to investment are normally published at later days and lower frequencies than financial and exchange rate data. Therefore, we adopt the second approach, namely, constructing an index of capital mobility based on the principle of interest parity, i.e. the expected change in the exchange rate is equal to the interest differential:[6]

$$E[\Delta r_j] = Id_j \tag{5}$$

Since it is well-known that (5) characterises an ideal, equilibrium state which has seldom been verified empirically, e.g. see (Isard 1995) and (de Vries 1995), a time series of rolling correlations of the two variables in (5) should serve as a good indicator of the changing degrees of capital mobility. Accordingly, we choose to define the index of capital mobility as:

$$0 \leqslant wk_{jt} = \frac{1 + corr(E[\Delta r_{jt}], Id_{jt})}{2} \leqslant 1 \tag{6}$$

and take six months as the length of the correlations in view of the fact that it usually takes a few months for capital markets to adjust to those policy

[6]Notice that (5) denotes covered interest parity when $E[\Delta r_j]$ is calculated from the difference between the spot rate and the forward rate, and uncovered interest parity when the forward rate is estimated.

changes which would affect the mobility. Specifically, the series $corr(E[\Delta r_{jt}], Id_{jt})$ in (6) are taken as the end-of-month observations from six-month rolling correlation coefficients using weekly data.[7] Graph 5 illustrates the eight wk_{jt} series thus calculated.

Once we have a measure for the infective risk, we could define eight shock variables for simple financial contagion as:

$$sk_{jt} = wk_{jt-1} \times \Delta r_{jt} \tag{7}$$

Table 4 gives key descriptive statistics of sk_{jt}.

Next, let us consider how to characterise the susceptible risk. In fact, most of the currency crisis models have tried to explain exchange rate collapses by the internal weakness of the susceptible, e.g. weak fundamentals or inconsistent macro policies, as evident from both the first-generation and the second generation models, see e.g. (Kaminsky *et al* 1998) and (Komulainen 1999). The variable sf in (1) measures effectively Korean susceptibility due to foreign debt.[8] On the other hand, the susceptibility could also be reflected by the significance of the shock variables sk_{jt} when we use them to model external financial contagion. Therefore, there is not much need to introduce a new, additional variable for the susceptible risk in the current modelling experiment, except, however, in connection with the third factor, namely, modelling the speculative impact.

Clearly, the third factor would make the transmitting mechanism of fi-

[7] Weekly forward exchange rates are estimated by weighted moving averages of the past four weeks whenever they are unavailable for certain economies. See the Appendix for the detailed description of data used.

[8] Unfortunately, a measure similar to wk_j for Korea would not work here because part of the index coincides with the modelled variable.

nancial contagion more complicated than what distributed-lags models are capable of characterising, using simply sk_{jt} as explanatory variables. Speculative activities and self-reinforcing expectation are normally characterised by nonlinear models with locally positive feedback, see e.g. (Froot and Obstfeld 1991), (Osler 1998a) and (Agliardi 1998), and are often represented empirically by an auxiliary residual ARCH regression and/or internal bubble variables, as in (1). However, these representations are inconvenient here if we want to embody the close link between speculative activities and the evolving status of both the susceptible and the infective, especially during turbulent periods. An empirical alternative is to use "discrete-state" or "switching regression" models, which have recently been increasingly applied to financial time series assumedly containing regime shifts or periodical bubbles, see e.g. (Hamilton 1989; 1990), (Engle and Hamilton 1990), (Kumar *et al* 1998), (Esquivel and Larraín 1998), and (Hall *et al* 1999). The hallmark of such models is a latent, discrete (often 0/1) variable, derived solely from the volatilities of the explained variable without using any information on possible sources of contagion. It is thus very difficult to use such models both for forecasts and for attaching feasible economic justifications to the models.[9]

Here, we opt to seek ways which would use as much directly observable information as possible rather than complicated estimation procedures, based on the very pragmatic viewpoint that extraordinarily turbulent currency fluctuations should result from certain external factors of impulse, which would remain more or less dormant during tranquil periods. In other words, we believe that it is empirically oversimplified to infer certain switching mechanism

[9] This problem is pointed out by van Norden (1996), who finds it almost impossible to differentiate between regime shifts or bubbles in reality and those specified in discrete-state models actually due to model misspecification.

in the marginal distribution of exchange rates from the observed excessive volatilities in data, and that the volatilities actually indicate serious lack of autonomy of the marginal distribution within a joint multivariate distribution during shock dissipating periods, see e.g. (Qin 1997) for further methodological arguments. Specifically, we choose to further compound the shock variables sk_{jt} with a certain measure of currency susceptibility of Korea, inspired by Kirman (1991; 1993), who develops a simple model of the herding behaviour of heterogeneous and interactive traders, which could lead to epidemics, by means of a random variable denoting the changing proportions of the fundamentalist traders versus the noise traders in a market.[10] The choice can be further justified by the observations that the Korean government has been perceived commonly by international financial investors as the implicit guarantee for any risky external borrowings by its private sectors, see e.g. (OECD 1994; 1996), and that the investors' perception of risk would become extremely sensitive to changes of Korea's international liquidity position, when currency crises have just occurred to its neighbours where the governments bear a similar image.[11] With reference to the idea of heterogeneous trading, we define the following index as Korea's international liquidity susceptibility:

$$w_t = 1 - 0.5^{\omega_t} \qquad \omega_t = \frac{\text{Government net total foreign reserves net of Gold}}{\text{Bank and other financial institution net total foreign liabilities}} \tag{8}$$

[10] Kirman adopts the idea of grouping traders into fundamentalist versus noise traders from (Frankel and Froot 1988). Since Kirman's work, more elaborate theoretical models of heterogenous and interactive agents in financial markets have been developed, e.g. see (Föllmer 1994), (Lux 1998), (Wermers 1999) and the very recent theorization of herding in connection with financial contagion by Calvo and Mendoza (1999).

[11] Dooley (2000) develops a theoretical model explaining similar phenomena.

using time series from the IMF's IFS data set.[12] Graph 6 illustrates how w_t, Korea's susceptibility, varies in the opposite direction of ω_t, the country's net foreign asset position. We could regard w_t as a proxy for the proportions of speculative activities in the currency markets since the index is controlled between 0 and 1.[13] In that way, we could incorporate in our models financial contagion induced by heterogeneous trading behaviour, since $sk_{jt} = w_t sk_{jt} + (1 - w_t) sk_{jt}$.

Based on the above analysis, we estimate the following two distributed-lags models, in a similar manner to the trade transmission models of the previous section:

$$\Delta r_t = \sum_{i=0}^{3}\sum_{j=1}^{8} \gamma_{ij} sk_{j,t-i} + \sum_{i=0}^{3}\sum_{j=1}^{8} \lambda_{ij} (w \cdot sk_j)_{t-i} + \epsilon_t$$

and

$$\widehat{\nu}_t = \sum_{i=0}^{3}\sum_{j=1}^{8} \gamma^*_{ij} sk_{j,t-i} + \sum_{i=0}^{3}\sum_{j=1}^{8} \lambda^*_{ij} (w \cdot sk_j)_{t-i} + \epsilon^*_t$$

Alternatively, we could use the pair of $(1 - w_t)sk_{jt}$ and $w_t sk_{jt}$, instead of

[12] Government net total foreign reserves is calculated by subtracting monetary authority liability from government total foreign reserves net of gold; Bank and other financial institution net total foreign liabilities is by subtracting foreign assets from liabilities of banks and other financial institutions. Since Korea's foreign currency market was not open until the end of the 1980s (see the (OECD 1994), we assume that the index takes, for the sample period prior to 1989, the same constant value as the first observation of 1989.

[13] It should be noted that a key obstacle in applying those game theory based models of heterogeneous traders is the statistical unobservability of the changing sizes of trader groups, e.g. noise traders versus fundamentalist traders. Osler has attempted to identify empirically the presence of noise trading using high-frequency, micro financial data, see (Osler 1998b) and (Chang and Osler 1999). But his method is not applicable here.

sk_{jt} and $w_t sk_{jt}$, as the explanatory variables. The present choice, however, enables us to interpret easily the first part of the model (the part with sk_{jt}) as representing the aggregate effect and the second part (the part with $w_t sk_{jt}$) as the disaggregate effect, so as to examine easily the feasibility of ignoring the disaggregate effect, i.e. $\lambda_{ij} = 0$ or $\lambda^*_{ij} = 0$, namely homogeneous trading reactions to currency crises. Notice that the more homogeneous the currency market activities the higher the degree of collinearity would occur between the $\gamma' s$ and $\lambda' s$. But perfect collinearity should not occur unless the w_t series converges to a constant. Therefore, we could utilise collinearity to study the degree of heterogenous behaviour in the market.

Reducing the above models via OLS estimation again by the general→specific approach, we get:

$$\begin{aligned}\Delta r_t = & -\underset{(.7128)}{1.8432}\, sk_{HK,t-3} + \underset{(.627)}{2.3786}\, (w \cdot sk_{SGP})_t - \underset{(.2993)}{0.5961}\, (w \cdot sk_{MAL})_t \\ & + \underset{(.3048)}{1.2036}\, (w \cdot sk_{TAI})_{t-1} + \underset{(1.22)}{4.7813}\, (w \cdot sk_{TW})_{t-3} + \underset{(.0117)}{\widehat{\epsilon}_t}\end{aligned} \tag{9}$$

and

$$\begin{aligned}\widehat{\nu}_t = & -\underset{(.2741)}{0.5737}\, sk_{MAL,t-1} - \underset{(.6128)}{1.2366}\, sk_{HK,t-3} + \underset{(.5628)}{2.3118}\, (w \cdot sk_{SGP})_t \\ & - \underset{(.3037)}{0.668}\, (w \cdot sk_{MAL})_t + \underset{(.8746)}{2.8841}\, (w \cdot sk_{MAL})_{t-1} - \underset{(.2533)}{0.8474}\, (w \cdot sk_{PH})_{t-2} + \underset{(.01006)}{\widehat{\epsilon^*_t}}\end{aligned} \tag{10}$$

Table 5 reports the relevant Granger non-causality test results of sk_{jt} and $w_t sk_{jt}$ on lagged Δr_t. Table 6 gives the diagnostic test results of (9) and (10). Graph 7 shows the forecasting results.

Discernibly, financial contagion have played a more important role than the trade contagion. It is especially noticeable from Graph 7 that model (9) has actually predicted a sharp rise in Δr_t by over 30% a month before the won actually collapsed in November and that the November's forecast is extremely close to the actual. This suggests that financial contagion was a major cause of the 1997 won crisis. Furthermore, the contagion is dominantly propagated by speculative activities, as the majority of the significant explanatory variables in both (9) and (10) are compound shock variables. These results are in agreement with a number of recent empirical studies and especially the findings of the common bank lender effect using commercial bank data in (Kaminsky and Reinhart 1999b) and (Rijckeghem and Weder 1999). Similar to the trade contagion models in the previous section, financial contagion is found to help further explain part of what (1) fails to explain, as shown by (10); and it also demonstrates the capacity of explaining away the residual ARCH effect found in (1), as shown by the diagnostic test results of table 6.

4 Synthesis

Since models (9) and (3) are non-nested with each other, or with the base model (1) either, it is natural to ask what the external contagion effects would be in the presence of those internal factors specified in (1). As mentioned before, model (10) or (4) will not be valid extensions of (1) unless all the explanatory variables in (10) or (4) are orthogonal with those in (1). Even if the orthogonality holds, (10) and (4) are still non-nested. Therefore, we now combine both trade and financial contagion into (1) and restart the estimation process from the following model:

$$\Delta r_t = \quad f(1) + \sum_{i=0}^{3}\sum_{j=1}^{8}\delta_{ij} st_{j,t-i} + \sum_{i=0}^{3}\sum_{j=1}^{8}\gamma_{ij} sk_{j,t-i} + \sum_{i=0}^{3}\sum_{j=1}^{8}\lambda_{ij}(w\cdot sk_j)_{t-i} + \varepsilon_t \tag{11}$$

where $f(1)$ denotes (1) without the appending ARCH regression.

Again by the same general→specific route, we reduce the model to the simplest possible version (see tables 7, 8 and 9 for details):

$$\begin{aligned}\widehat{\Delta r}_t = \quad & 0.0232 - 0.1278[\ln \tfrac{P_h}{P_f} - .01Id_{t-1} - .089sf]_{t-1} - 0.1539\Delta r_{t-1} \\ & +0.145\Delta_3 sf_{t-1} + 0.001\Delta_3(|sf|^{5.5})_{t-1} \\ & -0.0039st_{JP,t} - 0.0963st_{MAL,t} + 0.0896st_{TW,t-1} - 1.186st_{HK,t-1} \\ & +0.8948sk_{SGP,t} + 2.1664sk_{TW,t-1} - 3.694\Delta_2(w\cdot sk_{TW})_{t-1} \\ & +0.2482\Delta_2 sk_{MAL,t} - 2.703sk_{TAI,t-1} + 6.2243(w\cdot sk_{TAL})_{t-1} \\ & +0.8865\Delta sk_{IND,t-1} - 4.78(w\cdot sk_{IND})_{t-1} - 6.243sk_{HK,t-3} \\ & +27.368[(w\cdot sk_{HK})_t + (w\cdot sk_{HK})_{t-1}] - 19.56\Delta(w\cdot sk_{HK})_{t-2}\end{aligned} \tag{12}$$

It is remarkable to see from table 7 that (1) remains largely unaltered within (12) except for the loss of the $\Delta\ln(\frac{P_h}{P_f})_t$ term, and that the external shock variables are especially orthogonal with the two institutional variables representing Korea's internal debt problems. In fact, the explanatory power of most of the variables in (1) has been strengthened in view of their partial correlation coefficients (as in comparison with those in table 4 in (Qin 1999)), suggesting that the external contagion factors in (12) are largely complementary to the internal factors. Since (1) and (12) are non-nested models, encompassing tests of the two are performed, which indicate that (1) fails to encompass (12) parsimoniously.[14] Even though (12) is a much larger model than (1), its enlarged information content has mostly made up for the increased size, as judged by Schwartz information criterion.[15] All the parameter estimates remain relatively constant during the sample period, as shown from the constancy tests in table 7, and correlation between most of the explanatory variables is low, as shown in table 8. These statistical results provide us with a relatively solid ground for economic interpretation.

Model (12) has again confirmed that currency shocks via trade linkage have only played minor roles in destabilising the won rates, since three of the four significant shock variables are found to exert negative, i.e. stabilising, feedback effect, whereas Taiwan, the only one found with a positive feedback, was not a major infective since it survived the 1997 financial crisis.[16] The negative trade effect from Japan, Hong Kong and Malaysia suggests a strong competitive relationship between these economies and Korea in terms of foreign trade. Of the financial contagion, only Singapore and Malaysia are found to exert simple, i.e. aggregate, positive effect. Channels of financial shocks from the other economies are found to be more complicated, involving a significant amount of speculative effect. Notice, in particular, that speculative currency shocks in financial markets from Hong Kong and Thai-

[14] The results of three tests on whether (1) encompasses (12) are:

Cox	$N(0,1)$	-31.6274
Ericsson IV	$N(0,1)$	24.1178
Sargan	$\chi^2(15)$	47.3268
p-value		0.0000

[15] The values of the Schwartz criterion of the two models are only marginally different, namely -8.768 for (1) and -8.677 for (12).

[16] However, the Taiwan government gradually devalued its currency from July of 1997 to January 1998, as can be seen from graph 2.

land would propagate to the Korean won whereas an increase in speculative activities in Taiwan, Hong Kong and Indonesia would alleviate speculative pressure on the won. On the other hand, Japan is shown to exert no significant role in financial contagion and only a minor, stabilising role in trade shocks. These results suggest that external contagion is likely to come from similar or weaker, rather than stronger, economies of the region. The Philippines is totally absent in (12), due very probably to the highly substitutive nature of the shocks from this economy by those from Taiwan, Malaysia, and Indonesia, as shown from the relatively large correlation coefficients in tables 1 and 4.

Most importantly, we see that the enlarged information content of (12) has substantially improved the model forecastability of the 1997 crisis, especially in comparison with (1), as shown in graph 8. If we convert the forecasts into discrete, 0/1 series by simple demarcation lines of 10% and 5% devaluation respectively (see table 10), we find that (12) predicts a looming won collapse a month in advance of the actual crisis, whereas (1) fails badly. In comparison with those crisis-predicting models using the discrete-state regression method, model (12) is distinctly superior in that it is easily interpretable in terms of economics, robust in terms parameter estimates, simpler in terms of estimation and more useful in terms of prediction and simulation.

5 Concluding Remarks

The present modelling experiment uses eight Asian economies adjacent to Korea as the potential infective of currency contagion. It confirms that external contagion played a major role in the 1997 Korea's won collapse. Specifically, we find:

1. In the case of Korea, contagion via financial market linkage is found to be the most important infective channel of currency crises, whereas contagion via trade linkage is found to be only a minor channel.

2. The transmitting mechanism of the trade spillover is much simpler than that of financial contagion. Two crucial features of the financial contagion are identified here. First, the degree of infectivity of an economy varies with its level of exposure to the world financial market. An index of international capital mobility is thus devised on the basis of interest parity principle. Secondly, currency speculation forms a key force of amplifying financial market shocks, and such speculative activities are extremely sensitive to the market perception of the potential susceptibility of an economy. An index of the susceptibility is thus devised to construct currency shocks due particularly to speculative contagion. The resulting construct also allows for the interpretation, popularly seen in the theoretical literature, that the spread of financial market shocks is characterised by heterogeneous, rather than homogeneous, interactive trading activities.

3. The relative robustness of (12) and the fact that it is based on data prior to the 1997 Korean won crisis allows us to infer, in great details, about the roles of those significant sources of shocks which would propagate severe instability in the exchange rate returns. The model allows us not only to correspond the individual variables to different types of contagion, e.g. fundamentals contagion, real integration contagion, herding contagion and institutional contagion, as described by Fratzscher (1998) and Pritsker (1999), but also to assess their relative importance as well as their interactive roles with each other, e.g.

the internal factors with the external factors, and the short-run factors with the long-run equilibrium factor. We could also see from the identified sources of external shocks that contagion tends to come from neighbouring economies which are similar to, or weaker than, Korea in terms of financial structure and economic strength. We are thus able to draw from the model valuable insight not only for forecasting purposes but also for policy analyses.

4. Finally, the current experiment demonstrates that it is an empirically rewarding strategy to model currency crises in ways which are as economically sound and econometrically simple as possible. In particular, the advantage of specifying sources of external shocks over the adoption of statistically more sophisticated distributions or methods is evident from the comparison of the model type like (11) with discrete-state regression models, as already commented in the previous section. The advantage can also be seen from the absence of the ARCH effect in all the models experimented here, since an additional residual ARCH regression is merely an aggregate, reduced-form representation of second-moment shocks. Precise specification of the shocks would naturally improve model quality. But more importantly, it may also reveal interesting empirical evidence for further theoretical development.

Appendix: Data Sources

Most of the data series relating to Korea come from *Monthly Statistical Bulletin* (MSB) published by the Bank of Korea (BOK). The Bank also maintains a web-site data bank at http://www.bok.or.kr/kobank/owa/. The rest of the series come from either the Data Stream software (DS) or the *International Financial Statistics* (IFS) *Monthly* by the IMF. The sample period is 1986–1998.

- Series used in the base model (all monthly):

  R: exchange rate of won per U.S. dollar, end of the period (BOK)

  I_h: money market interest rate of Korea (IFS)

  I_f: Federal funds rate of US (IFS)

  P_h: wholesale price index of Korea (1990=100) (IFS)

  P_f: wholesale price index of US (1990=100) (IFS)

  Sf: foreign liability/total loans of deposit money banks of Korea, end of period, million won (BOK)

- Series used to construct *st* (all monthly):

  Korea's exports to Hong Kong, 1000US$ (BOK)

  Korea's exports to Indonesia, 1000US$ (BOK)

  Korea's exports to Japan, 1000US$ (BOK)

  Korea's exports to Malaysia, 1000US$ (BOK)

  Korea's exports to Philippines, 1000US$ (BOK)

  Korea's exports to Singapore, 1000US$ (BOK)

Korea's exports to Taiwan, 1000US$ (BOK)

Korea's exports to Thailand, 1000US$ (BOK)

Korea's total exports (FOB) million US$ (BOK)

Exchange rate: Hong Kong $ to one US $ (DS)

Exchange rate: Indonesian Rupiah to one US $ (DS)

Exchange rate: Japanese Yen to one US $ (DS)

Exchange rate: Malaysian Ringgit to one US $ (DS)

Exchange rate: Philippine Peso to one US $ (DS)

Exchange rate: Thai Baht to one US $ (DS)

Exchange rate: Singapore $ to one US $ (DS)

Exchange rate: Taiwan new $ to one US $ (DS)

- Series used to construct sk (all weakly from DS):

Exchange rate: Hong Kong $ to one US $

Hong Kong $ to one US $ 1-month forward rate (Barclays Bank International)

Exchange rate: Indonesian Rupiah to one US $

Indonesian Rupiah to one US $ 1-month forward rate for 1997-98 (WM/Reuters); forward rate calculated using 4-weekly weighted moving average of the actual rate for the period 1986-96 with the weights of 0.4, 0.3, 0.2, 0.1

Exchange rate: Japanese Yen to one US $

Japanese Yen to one US $ 1-month forward rate

Exchange rate: Malaysian Ringgit to one US $

Malaysian Ringgit to one US $ 1-month forward rate (Barclays Bank International); data of the final sample year is converted from Malaysian Ringgit to one UK £ 1-month forward rate

Exchange rate: Philippine Peso to one US $

Philippine Peso to one US $ 1-month forward rate for 1997-98 (WM/Reuters); forward rate calculated using 4-weekly weighted moving average of the actual rate for the period 1986-96 with the weights of 0.4, 0.3, 0.2, 0.1

Exchange rate: Thai Baht to one US $

Thai Baht to one US $ 1-month forward rate for 1997-98 (WM/Reuters); forward rate calculated using 4-weekly weighted moving average of the actual rate for the period 1986-96 with the weights of 0.4, 0.3, 0.2, 0.1

Exchange rate: Singapore $ to one US $

Singapore $ to one US $ 1-month forward rate (Barclays Bank International)

Exchange rate: Taiwan new $ to one US $

Taiwan new $ to one US $ 1-month forward rate for 1992-98 (WM/Reuters); forward rate calculated using 4-weekly weighted moving average of the actual rate for the period 1986-91 with the weights of 0.4, 0.3, 0.2, 0.1

US commercial paper discount 30 day – middle rate, used as the foreign interest rate

Hong Kong interbank 1 month – middle rate

Indonesia deposit 1 month – middle rate for 1989-98; use saving bank 90 day rate to approximate the rates for 1986-88

Japan interbank 1 month – offered rate

Malaysia interbank 1 month – middle rate

Philippine time deposit 35 day – middle rate for 1993M7-98; use Treasury bill 91 day rates to approximate the rates for 1986-93M6

Singapore interbank Month - middle rate

Thai interbank 1 month - offered rate for 1992-98; use monthly 3 to 6 month time deposit rates to extrapolate the rates for 1986-91

Taiwan money market 30 day – middle rate for 1993M8-98; use deposit bank 1 month rate as proxy for 1986-93M7

- Series used to construct w (all monthly):

Total reserves minus gold, million US $ (BOK & IFS)

Monetary authority: Other liabilities, million US $ (BOK & IFS)

Commercial banks: Foreign assets, million US $ (BOK & IFS)

Deposit money banks: Foreign liabilities, million US $ (BOK & IFS)

Other financial institutions: Foreign assets, million US $ (BOK & IFS)

Other financial institutions: Foreign liabilities, million US $ (BOK & IFS)

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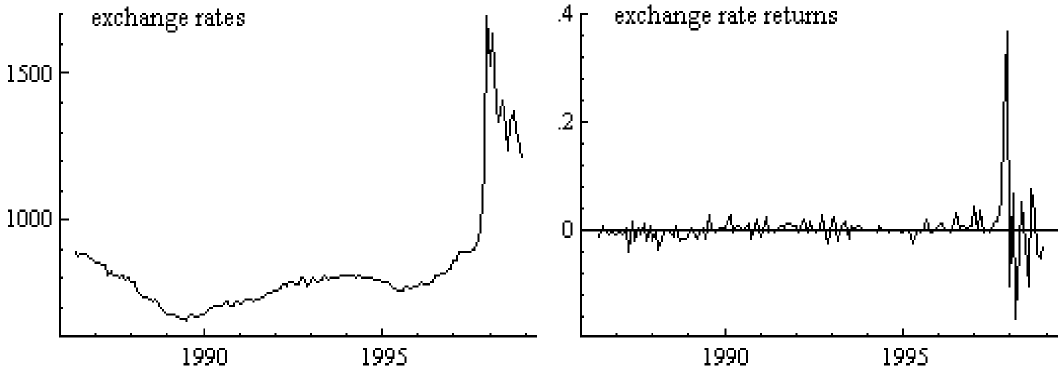
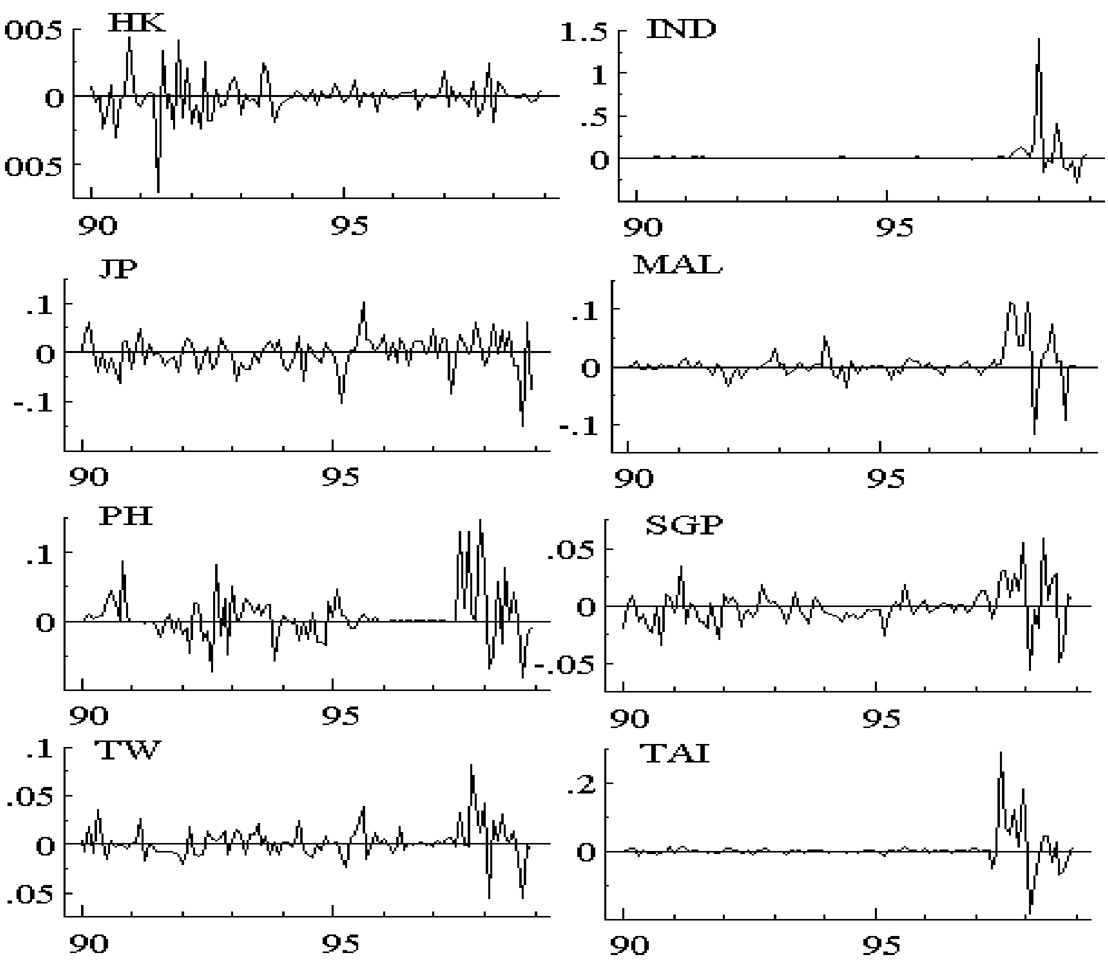
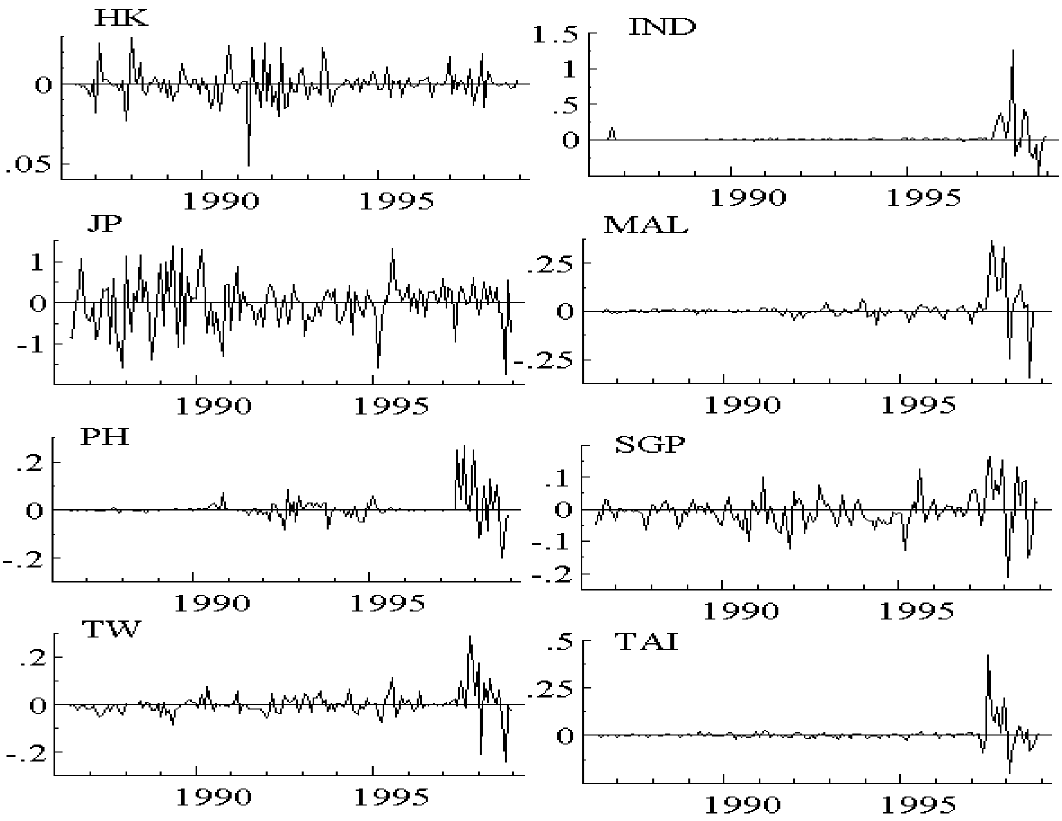
Graph 1. Nominal won/US$ rates and its returns (monthly)



Graph 2. Exchange rate returns of the eight neighbouring economies

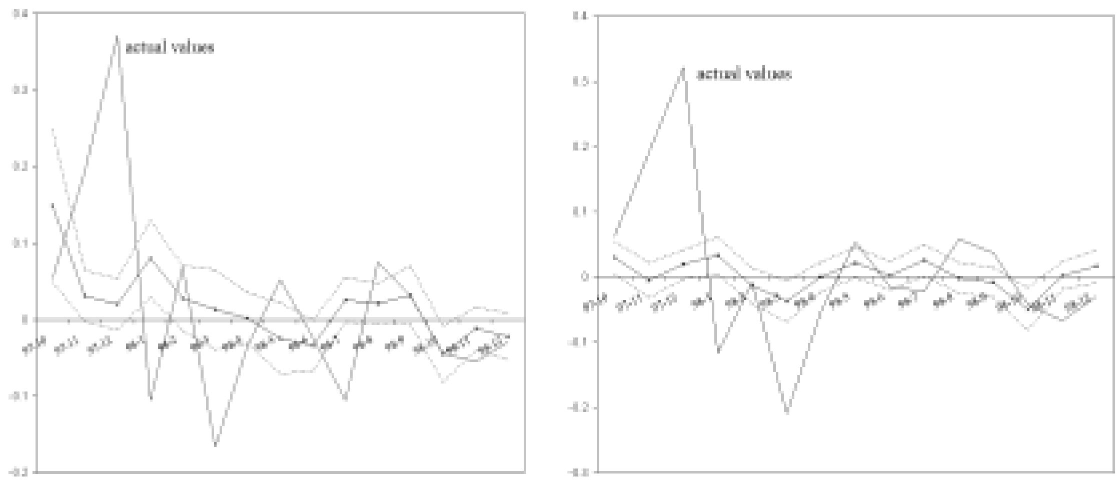


Graph 3. st_{jt} – Currency shocks via trade linkage

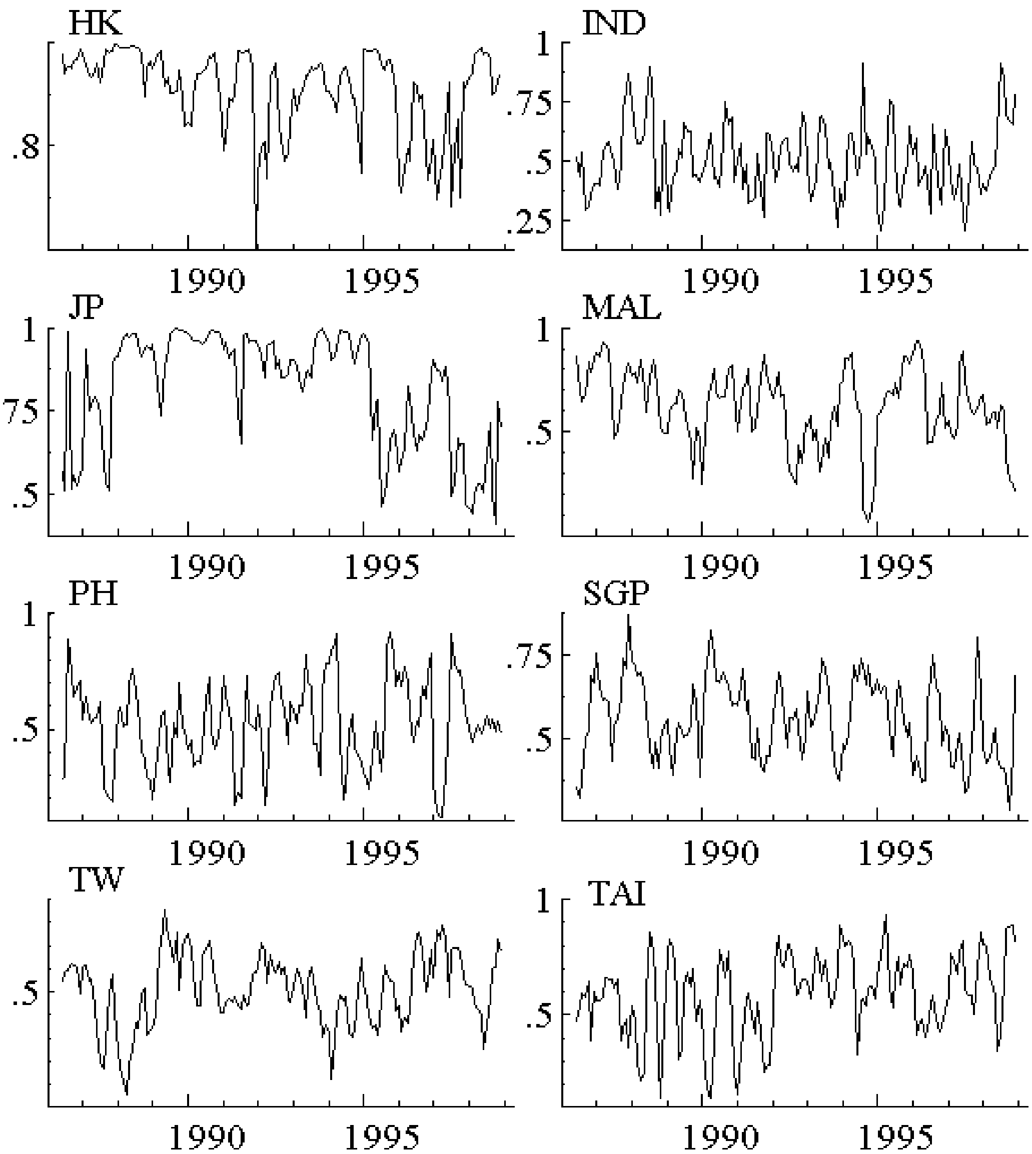


Graph 4. Forecasts by Models — Left: (3); Right: (4)

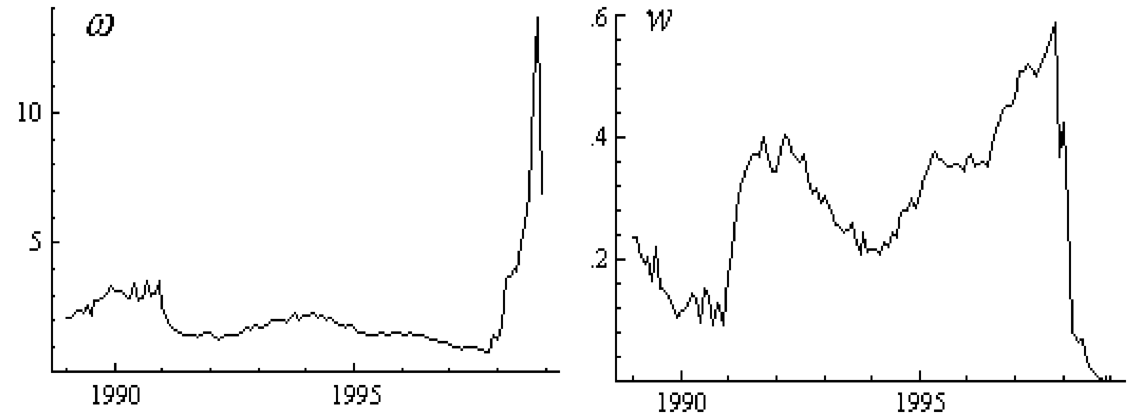
(marked solid lines amid the 95% confidence intervals in dotted lines)



Graph 5. wk_{jt} – indices of international capital mobility

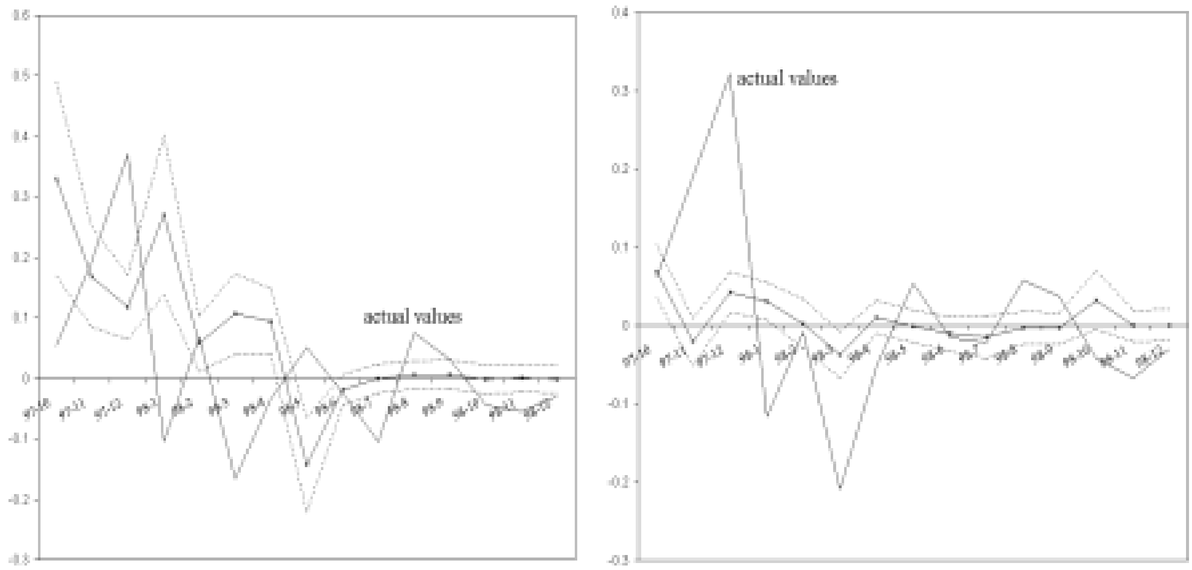


Graph 6. Indices of Korea's exchange rate susceptibility



Graph 7. Forecasts by Models — Left: (9); Right: (10)

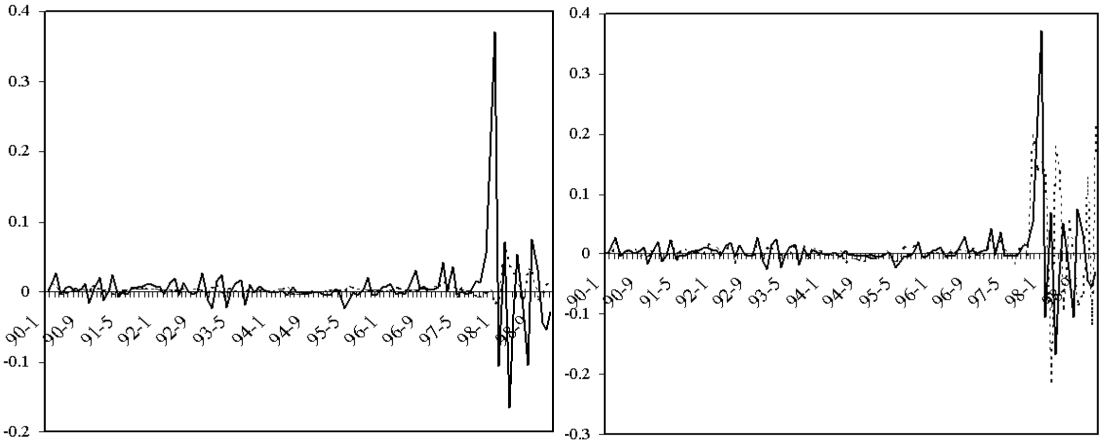
(marked solid lines amid the 95% confidence intervals in dotted lines)



Graph 8. Actual versus fitted and forecast values of Δr_t

Left: model (1); Right: Model (12)

Actual values: solid line; Fitted and forecast values: dotted lines



(marked solid lines amid the 95% confidence intervals in dotted lines)

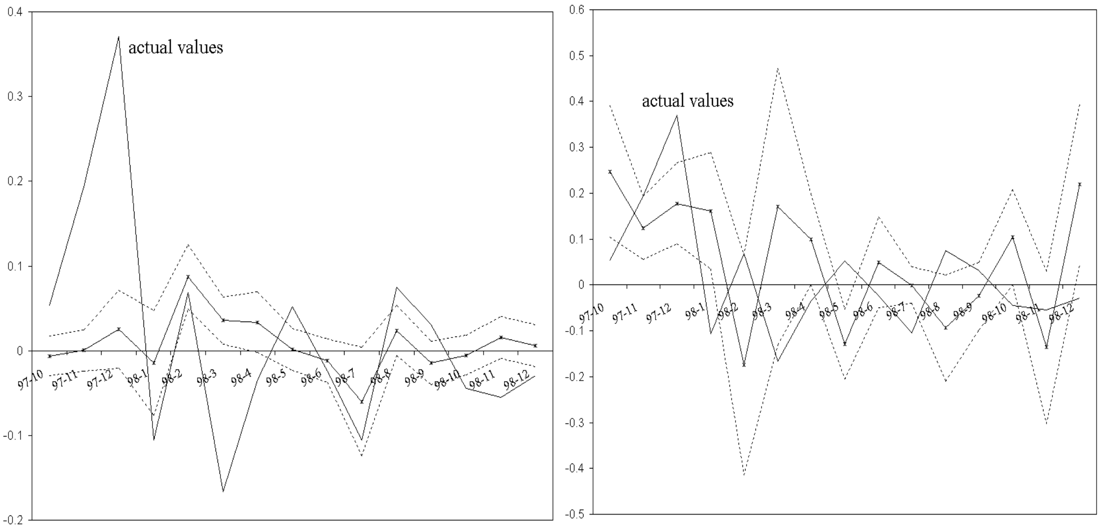


Table 1. Descriptive Statistics of st_{jt}

st_{jt}	HK	IND	JP	MAL	PH	SGP	TW	TAI
mean	-.0004	.0128	-.043	.0046	.0055	-.008	-.0017	.004
st.dev.	.0099	.0446	.58	.0439	.0377	.0414	.0304	.04
	Correlation							
HK	1	-.05919	.02642	-.00289	-.05146	.0854	.08163	-.0178
IND		1	.06355	.80099	.65559	.38585	.08044	.49535
JP			1	.12917	.01166	.53871	.19289	.23261
MAL				1	.51224	.47961	.12291	.48498
PH					1	.2665	.15996	.63165
SGP						1	.3391	.51151
TW							1	.28796
TAI								1

Table 2. Granger Non-causality Tests: st_{jt} on lagged Δr_t

(3 lags; sample: 1986M6 - 1997M9)

st_{jt}	HK	IND	JP	MAL	PH	SGP	TW	TAI
$F_{(3,129)}$ [p value]	0.6082 [0.6108]	0.8137 [0.4885]	0.9801 [0.4044]	0.1851 [0.9064]	0.0817 [0.9699]	0.4602 [0.7105]	0.6741 [0.5694]	0.3607 [0.7815]

Table 3. Model Tests

Alternative hypotheses	Equation (3)	Equation (4)
	Test statistics [$p-$value]	
residual autocorrelation	$F(7,130) = 3.5567$ [0.0016]	$F(7,130) = 1.7083$ [0.1124]
residual ARCH	$F(1,135) = 0.019$ [0.8907]	$F(7,123) = 0.6511$ [0.7128]
residual heteroscedasticity	$F(8,128) = 0.474$ [0.8725]	$F(7,129) = 1.1112$ [0.3600]
residual non-normality	$\chi^2(2) = 6.5311$ [0.0382]	$\chi^2(2) = 2.4732$ [0.2904]
RESET	$F(1,136) = 4.4534$ [0.0368]	$F(1,204) = 0.0722$ [0.7885]

Table 4. Descriptive Statistics of sk_{jt}

sk_{jt}	HK	IND	JP	MAL	PH	SGP	TW	TAI
mean	-.0000423	.00425	-.002627	.00135	.002688	-.00112	.00127	.00134
st.dev.	.0014	.0435	.02919	.01657	.01969	.0083	.01942	.02748
	Correlation							
HK	1	-.04545	.03833	.05245	.03116	.13126	-.0162	-.0305
IND		1	.1234	.40177	.3289	.3613	.44417	.44738
JP			1	.18245	.03317	.50587	.21677	.17961
MAL				1	.54755	.58001	.7089	.67259
PH					1	.33327	.60509	.59761
SGP						1	.60389	.55812
TW							1	.97427
TAI								1

Table 5. Granger Non-causality Tests: sk_{jt} and $w_t sk_{jt}$ on lagged Δr_t

(3 lags; sample: 1986M10 - 1997M9)

sk_{jt}	HK	IND	JP	MAL	PH	SGP	TW	TAI
F (3,128) [p value]	0.4955 [0.6861]	0.4778 [0.6983]	0.9967 [0.3967]	0.2771 [0.8418]	0.1915 [0.9021]	0.7903 [0.5014]	0.4525 [0.7160]	0.2075 [0.8911]
$w_t sk_{jt}$								
F (3,128) [p value]	0.5413 [0.6549]	0.6417 [0.5895]	0.9492 [0.4190]	0.1936 [0.9006]	0.1740 [0.9139]	0.6529 [0.5825]	0.3354 [0.7997]	0.1421 [0.9345]

Table 6. Model Tests

Alternative hypotheses	Equation (9)	Equation (10)
	Test statistics [$p-$value]	
residual autocorrelation	$F(3,124) = 1.9895$ [0.119]	$F(3,123) = 1.2428$ [0.2972]
residual ARCH	$F(3,121) = 0.6595$ [0.5786]	$F(3,120) = 0.5883$ [0.6238]
residual heteroscedasticity	$F(10,116) = 0.3381$ [0.9497]	$F(12,113) = 0.428$ [0.9494]
residual non-normality	$\chi^2(2) = 3.3349$ [0.1887]	$\chi^2(2) = 10.783$ [0.0046]
RESET	$F(1,204) = 2.6501$ [0.106]	$F(1,204) = 0.2717$ [0.6031]

Table 7. The simpliest version of (12)

Sample period: 86M10 - 97M9

Explanatory variables	coefficient estimates	standard errors	partial R^2	constancy tests $5\%_{\text{c.v.}=0.47}$
constant	0.0232	.00579	.1255	0.11
$[\ln \frac{P_h}{P_f} - .01Id_{t-1} - .089sf]_{t-1}$	$-.1278$	.03632	.0995	0.12
Δr_{t-1}	$-.1539$	.07213	.0391	0.19
$\Delta_3 sf_{t-1}$	0.145	.023	.2615	0.14
$\Delta_3(\lvert sf\rvert^{5.5})_{t-1}$	0.001	.00017	.2445	0.20
$st_{JP,t}$	$-.0039$	.0019	.0341	0.07
$st_{MAL,t}$	$-.0963$	.0425	.0439	0.05
$st_{TW,t-1}$	0.0896	.0317	.0667	0.14
$st_{HK,t-1}$	-1.186	.2525	.1646	0.19
$sk_{SGP,t}$	0.8948	.1915	.1631	0.16
$sk_{TW,t-1}$	2.1664	.5389	.1261	0.02
$\Delta_2(w \cdot sk_{TW})_{t-1}$	-3.694	1.151	.0842	0.02
$\Delta_2 sk_{MAL,t}$	0.2482	.0998	.0144	0.36
$sk_{TAI,t-1}$	-2.703	.7808	.0966	0.02
$(w \cdot sk_{TAL})_{t-1}$	6.2243	1.751	.1014	0.01
$\Delta sk_{IND,t-1}$	0.8865	.4213	.038	0.10
$(w \cdot sk_{IND})_{t-1}$	-4.78	2.17	.0415	0.09
$sk_{HK,t-3}$	-6.243	1.426	.1461	0.14
$(w \cdot sk_{HK})_t + (w \cdot sk_{HK})_{t-1}$	27.368	6.303	.1441	0.07
$\Delta(w \cdot sk_{HK})_{t-2}$	-19.56	5.152	.114	0.03
$\sigma_{\widehat{\varepsilon}}$	.0097	/	/	0.046

Table 8. Correlation coefficients of the regressors in (12)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1.00																		
2	0.11	1.00																	
3	0.30	0.31	1.00																
4	-0.13	-0.08	-0.73	1.00															
5	0.08	-0.03	-0.01	0.10	1.00														
6	0.29	0.31	-0.01	0.03	0.12	1.00													
7	0.18	0.11	0.13	-0.05	0.02	0.19	1.00												
8	0.05	0.14	-0.10	0.16	-0.02	0.05	-0.02	1.00											
9	0.26	0.24	0.02	0.06	0.51	0.58	0.11	0.05	1.00										
10	0.02	0.34	0.09	-0.03	0.04	0.40	0.54	-0.03	0.16	1.00									
11	0.02	-0.12	-0.17	0.04	0.01	0.27	0.34	-0.05	0.04	0.67	1.00								
12	0.19	0.05	-0.21	0.04	0.15	0.61	-0.11	0.11	0.35	0.00	0.21	1.00							
13	0.00	0.27	0.06	-0.02	0.03	0.38	0.52	-0.05	0.13	0.97	0.73	0.04	1.00						
14	0.10	0.19	0.09	-0.02	0.02	0.47	0.46	-0.05	0.14	0.91	0.74	0.12	0.93	1.00					
15	0.03	-0.04	-0.05	0.00	-0.08	0.03	0.42	-0.06	-0.11	0.42	0.33	0.04	0.44	0.34	1.00				
16	0.01	-0.02	0.34	-0.08	0.04	-0.11	0.42	-0.11	-0.12	0.48	0.20	-0.45	0.47	0.46	0.51	1.00			
17	0.06	0.01	0.03	-0.01	0.13	-0.04	-0.05	0.01	0.08	-0.04	-0.01	-0.05	-0.05	-0.04	-0.07	-0.02	1.00		
18	0.06	0.09	-0.13	0.19	0.03	0.03	0.03	0.59	0.14	-0.10	0.00	0.14	-0.08	-0.07	-0.06	-0.13	-0.07	1.00	
19	-0.02	-0.07	-0.03	0.03	-0.12	-0.02	0.05	-0.22	-0.10	0.06	0.01	-0.01	0.08	0.06	0.16	0.12	-0.74	-0.13	1.00

$1 = \left(ln \frac{P_k}{P_f} - .01\, Id_{t-1} - .089\, sf \right)_{t-1}$ $2 = \Delta r_{t-1}$ $3 = \Delta_3 sf_{t-1}$ $4 = \Delta_3 \left(|sf_{t-1}|^{5.5} \right)$ $5 = st_{JP,t}$

$6 = st_{MAL,t}$ $7 = st_{TW,t-1}$ $8 = st_{HK,t-1}$ $9 = sk_{SGP,t}$ $10 = sk_{TW,t-1}$

$11 = \Delta_2 (w \cdot sk_{TW})_{t-1}$ $12 = \Delta_2 sk_{MAL,t-1}$ $13 = sk_{TAI,t-1}$ $14 = (w \cdot sk_{TAI})_{t-1}$ $15 = \Delta sk_{IND,t-1}$

$16 = (w \cdot sk_{IND})_{t-1}$ $17 = sk_{HK,t-3}$ $18 = (w \cdot sk_{HK})_t + (w \cdot sk_{HK})_{t-1}$ $19 = \Delta (w \cdot sk_{HK})_{t-2}$

Table 9. Diagnostic tests of (12)

Alternative hypotheses	Test statistics	$p-$ value
residual autocorrelation	$F(3, 109) = 0.5175$	0.6711
residual ARCH	$F(3, 106) = 0.2186$	0.8833
residual heteroscedasticity	$F(39, 72) = 0.4532$	0.9958
residual non-normality	$\chi^2(2) = 10.312$	0.0058
RESET	$F(1, 111) = 0.4156$	0.5205

Table 10. Crisis prediction by discrete 0/1 series using (1) and (12)

%	97M9	97M10	97M11	97M12	98M1	98M2	98M3	98M4	98M5
Δr_t	1.36	5.34	19.3	37.07	-10.57	6.84	-16.62	-3.46	5.18
10%↑	0	0	1	1	0	0	0	0	0
5%↑	0	1	1	1	0	1	0	0	1
fitted values by (1) with [95% band]; 5-10%↑ indicates the demarcation of the 0/1 series									
$\widehat{\Delta r_t}$	-0.96 [±2.28]	-0.73 [±2.27]	-0.10 [±2.38]	-2.04 [±4.5]	-2.02 [±6.02]	9.29 [±3.73]	3.58 [±2.73]	3.55 [±3.51]	-0.01 [±2.41]
10%↑	0	0	0	0	0	0	0	0	0
5%↑	0	0	0	0	0	1	0	0	0
fitted values by (12) with [95% band]; 5-10%↑ indicates the demarcation of the 0/1 series									
$\widehat{\Delta r_t}$	-0.13 [±4.18]	19.75 [±14.45]	13.99 [±7.06]	15.06 [±8.94]	12.86 [±12.93]	-21.25 [±24.47]	17.85 [±30.68]	13.38 [±9.71]	-9.13 [±7.44]
10%↑	0	1	1	1	1	0	1	1	0
5%↑	0	1	1	1	1	0	1	1	0