Measuring Contagion under Simultaneity

Johannes Fedderke

ERSA & University of Cape Town

The Motivation: conceptual

- Presence, repetition and severity of financial crises
- Propagation
- Distinction: economic linkages vs pure
- Policy: limited vs. proactive

The Motivation: methodological

- Need for measurement of propagation
- Distinction between"shift" and "pure"
- There exist priors: Rigobon
- But: feedback?

Outline:

- Priors in the Literature
- Background
- The Problem: simultaneity
- The Data
- Empirical Results:
  - Correlation
  - Long Run Structural
  - Rigobon
  - S-twist
- Conclusions

Priors in the Literature

- "Shift" contagion: fundamentals:
  - trade: direct & competition in third markets
  - similar initial conditions
  - financial linkages
- "Pure" contagion: no fundamentals; investor perception alone.

Priors in the Literature

- Contagion associated with high frequency events:
  - Measured on stock market returns, interest rates, exchange rates or a combination of these
  - Data plagued by simultaneous equations, omitted variable, conditional and unconditional heteroscedasticity, serial correlation, non-linearity and non-normality problems
- Econometric tests for contagion either:
  - Test for shifts in the transmission mechanism (tests based on parameter stability)
  - Measure different channels through which shocks propagate across countries

Priors in the Literature

- Most widely used methodologies in contagion literature:
  - Linear (OLS) regressions
  - Probit/Logit models
  - Tests based on principal components and correlation coefficients
- Rigobon (2000, 2003, 2004):
  - Address the identification problem of simultaneous equations in the presence of heteroskedasticity
- Rigobon (1999), Forbes et al. (2001), Forbes and Rigobon (2005):
  - Establish a framework with more restrictive set of identifying assumptions in order to simultaneously correct for heteroscedasticity, endogeneity and omitted variables
  - Correcting the heteroskedasticity biases in cross-market correlation coefficients

Priors in the Literature

- Other methodologies used in contagion literature:
  - Measures based on ARCH models (Edwards and Susmel, 2000)
  - Cointegration based models (Cashin et al, 1995; Longuin and Slonick, 1995)
  - Switching regimes models (Longuin and Slonick, 1995)
  - Factor regression models (Sentana and Fiorentini, 1999)
  - Limited dependent models under heteroscedasticity (Chen and Kahn, 1999; Klein and Vella, 2000)
  - Bayesian time-varying coefficient models (Ciccarelli and Rebucci, 2003)
  - Dynamic equilibrium models (Pavlova and Rigobon, 2005)
  - Panel estimations (Bayoumi et al, 2007)

Background

- Consider the case of two variables: y_t and x_t, to represent say stock market indexes, or exchange rates of two countries.
- Let them be associated by:

$$y_t = \beta x_t + \varepsilon_t \tag{1}$$

where:

- ε_t represents country-y's specific shocks,
- $x_t = \eta_t$, with η_t representing country-x's country specific shocks,
- and $E[\eta_t \varepsilon_t] = 0, E[\varepsilon_t \varepsilon_t'] = \sigma_\varepsilon^2, E[\eta_t \eta_t'] = \sigma_\eta^2$.

Background

- Now split the sample, with the variance of η_t increasing: $var\left(\eta_t^h\right) > var\left(\eta_t^l\right)$,
- The β-estimates in the two samples should be consistent:

$$\begin{aligned} y_t^h &= \beta^h x_t^h + \varepsilon_t \\ y_t^l &= \beta^l x_t^l + \varepsilon_t \end{aligned}$$

  with $plim\beta^h = plim\beta^l$.
- Since $var\left(x_t^h\right) > var\left(x_t^l\right)$, for consistent $\beta's$, $cov\left(x_t^h, y_t^h\right) > cov\left(x_t^l, y_t^l\right)$, and by the same proportion as for $var\left(x_t\right)$.

Background

- The original formulation of the problem:
  - $var\left(y_t\right)$ is homogeneous of degree one on $var\left(x_t\right)$ and $var\left(\varepsilon_t\right)$,
  - $\partial var\left(x_t\right)/\partial t > 0$, but $\partial \beta^i/\partial t = \partial var\left(\varepsilon_t\right)/\partial t = 0$ over the two samples,
  - $\Longrightarrow \partial var\left(y_t\right)/\partial t < \partial var\left(x_t\right)/\partial t$,
  - $\Longrightarrow \partial var\left(y_t\right)/\partial t < \partial cov\left(x_t, y_t\right)/\partial t$
  - $\Longrightarrow$ such that the correlation coefficient must increase, with $\rho^h > \rho^l$, since the noise/signal ratio in equation (1) is reduced.

Background

- Correct the bias in the correlation. Define:

$$var\left(x_t^h\right) = \left(1+\delta_t\right)\sigma_x^2$$

where $var\left(x_t^h\right)$ is the (conditional) variance of x_t during the period of increased variance, while σ_x^2 is the (unconditional) variance of x_t over the full sample.

- $\Longrightarrow cov\left(x_t^h, y_t^h\right) = \left(1+\delta_t\right)\sigma_{xy}$ where σ_{xy} is the unconditional covariance.
- Then:

$$\begin{aligned} var\left(y_t^h\right) &= \left(1+\delta_t\rho^2\right)\sigma_y^2 \\ \rho_t^h &= \rho\left[\frac{1+\delta_t}{1+\delta_t\rho^2}\right]^{\frac{1}{2}} \end{aligned}$$

with ρ the unconditional correlation, and σ_y^2 the unconditional variance of y_t.

Background

- Simple substitution gives the unconditional, unbiased correlation coefficient of Rigobon (1998):

$$\rho = \rho_t^h \cdot \left[\frac{var\left(x_t^h\right)}{\sigma_x^2} \cdot \frac{\sigma_y^2}{var\left(y_t^h\right)} \right]^{-\frac{1}{2}}$$

- First test of non-fundamentals (pure contagion) led explanation of contagion
  - Supposition: $\frac{var\left(x_t^h\right)}{\sigma_x^2} > \frac{var\left(y_t^h\right)}{\sigma_y^2}$.
  - Satisfied: $\left[\frac{var\left(x_t^h\right)}{\sigma_x^2} \cdot \frac{\sigma_y^2}{var\left(y_t^h\right)} \right]^{-\frac{1}{2}} < 1$,
  - Violated: $\left[\frac{var\left(x_t^h\right)}{\sigma_x^2} \cdot \frac{\sigma_y^2}{var\left(y_t^h\right)} \right]^{-\frac{1}{2}} > 1$.

The Problem of this Paper

- Test premised on absence of simultaneity between market indicator variables
- Let:

$$\begin{aligned} y_t &= \beta z_t + \varepsilon_t \\ x_t &= z_t + \eta_t \end{aligned}$$

where:

- z_t denotes either an aggregate unobservable variable, or the impact of endogenous variables, with the coefficient of z_t in the x_t-equation normalized on unity, and where
- only y_t and x_t observables.
- $\Longrightarrow E\left[\eta_t \varepsilon_t\right] = 0, E\left[\varepsilon_t \varepsilon_t'\right] = \sigma_\varepsilon^2, E\left[\eta_t \eta_t'\right] = \sigma_\eta^2$ condition is violated.

Test Allowing for Simultaneity

- Let $var\left(x_t\right)$ increase either by a shock to z_t or η_t. In particular, assume :

$$var\left(x_t^h\right) = \left(1+\delta_z\right)\sigma_z^2 + \left(1+\delta_\eta\right)\sigma_\eta^2$$

  $\delta_z, \delta_\eta \geq 0$, and $\sigma_z^2, \sigma_\eta^2$ denoting the relevant unconditional variances.

- Then:

$$\begin{aligned} var\left(y_t^h\right) &= \beta^2\left(1+\delta_z\right)\sigma_z^2 + \sigma_\varepsilon^2 \\ cov\left(x_t^h, y_t^h\right) &= \beta\left(1+\delta_z\right)\sigma_z^2 \end{aligned}$$

Test Allowing for Simultaneity

- Hence the unconditional and conditional correlation coefficients are now given by:

$$\rho = \frac{\beta\sigma_z^2}{\left[\left(\beta^2\sigma_z^2+\sigma_\varepsilon^2\right)\left(\sigma_z^2+\sigma_\eta^2\right)\right]^{\frac{1}{2}}}$$

$$\rho^h = \frac{\beta\left(1+\delta_z\right)\sigma_z^2}{\left[\left(\beta^2\left(1+\delta_z\right)\sigma_z^2+\sigma_\varepsilon^2\right)\left(\left(1+\delta_z\right)\sigma_z^2+\left(1+\delta_\eta\right)\sigma_\eta^2\right)\right]^{\frac{1}{2}}}$$

Test Allowing for Simultaneity

- By defining $\lambda = \frac{\rho}{\rho^h}$, and by virtue of simple substitution, it follows trivially that:

$$\lambda < 1 \; iff \; \frac{cov\left(x_t, y_t\right)}{cov\left(x_t^h, y_t^h\right)} < \left(\frac{var\left(x_t^h\right)}{\sigma_x^2} \cdot \frac{var\left(y_t^h\right)}{\sigma_y^2} \right)$$

$$\lambda > 1 \; iff \; \frac{cov\left(x_t, y_t\right)}{cov\left(x_t^h, y_t^h\right)} > \left(\frac{var\left(x_t^h\right)}{\sigma_x^2} \cdot \frac{var\left(y_t^h\right)}{\sigma_y^2} \right)$$

Test Allowing for Simultaneity

- Note that:

$$\begin{aligned} \delta_z &\rightarrow 0, \rho^h < \rho \\ \delta_\eta &\rightarrow 0, \rho^h > \rho \end{aligned}$$

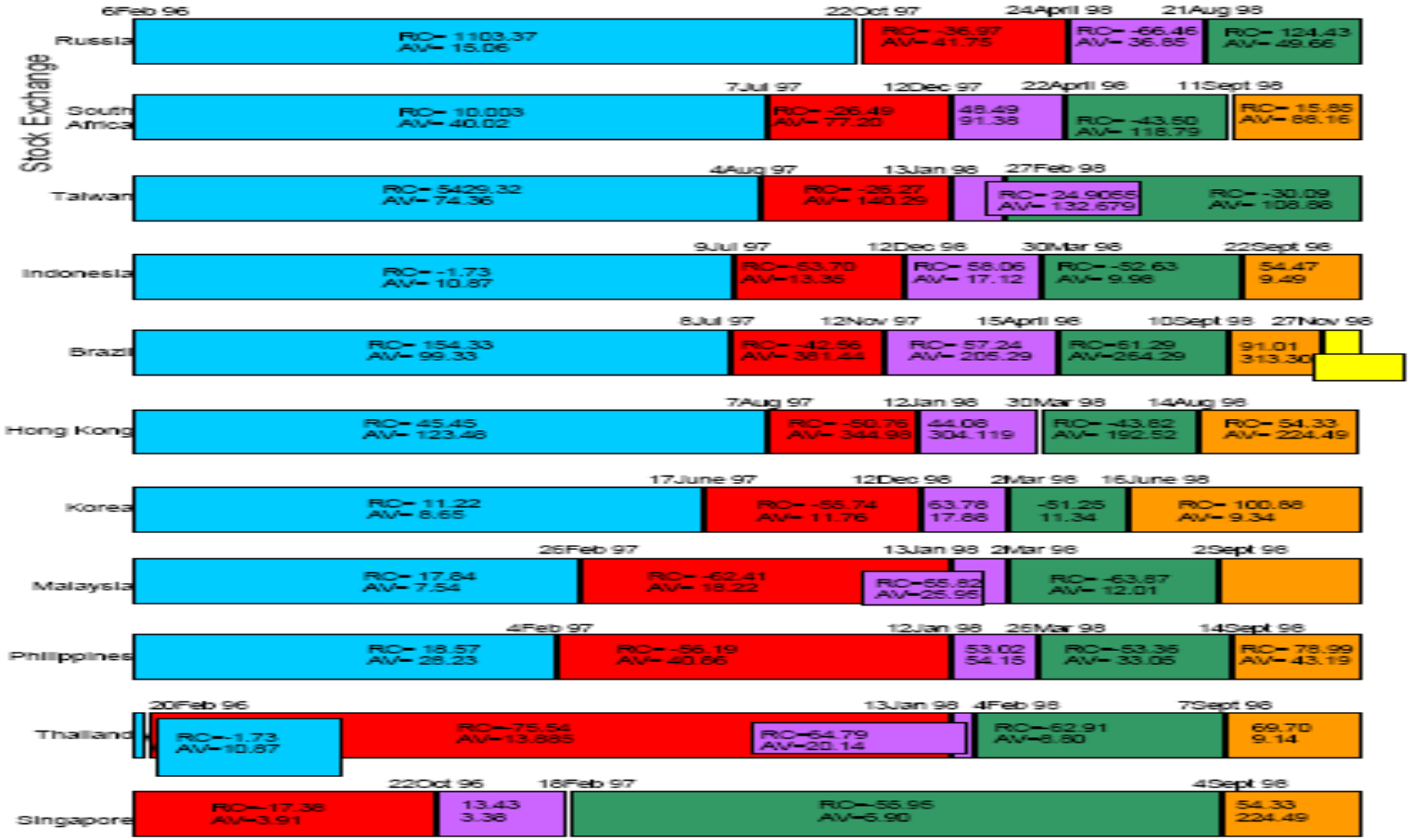
- Hence:
  - $\lambda > 1 \Rightarrow \delta_z \rightarrow 0, \Longrightarrow$ shock to the system emerges through η_t not z_t.
  - $\lambda < 1 \Rightarrow \delta_\eta \rightarrow 0, \Longrightarrow$ shock to the system emerges through z_t not η_t.

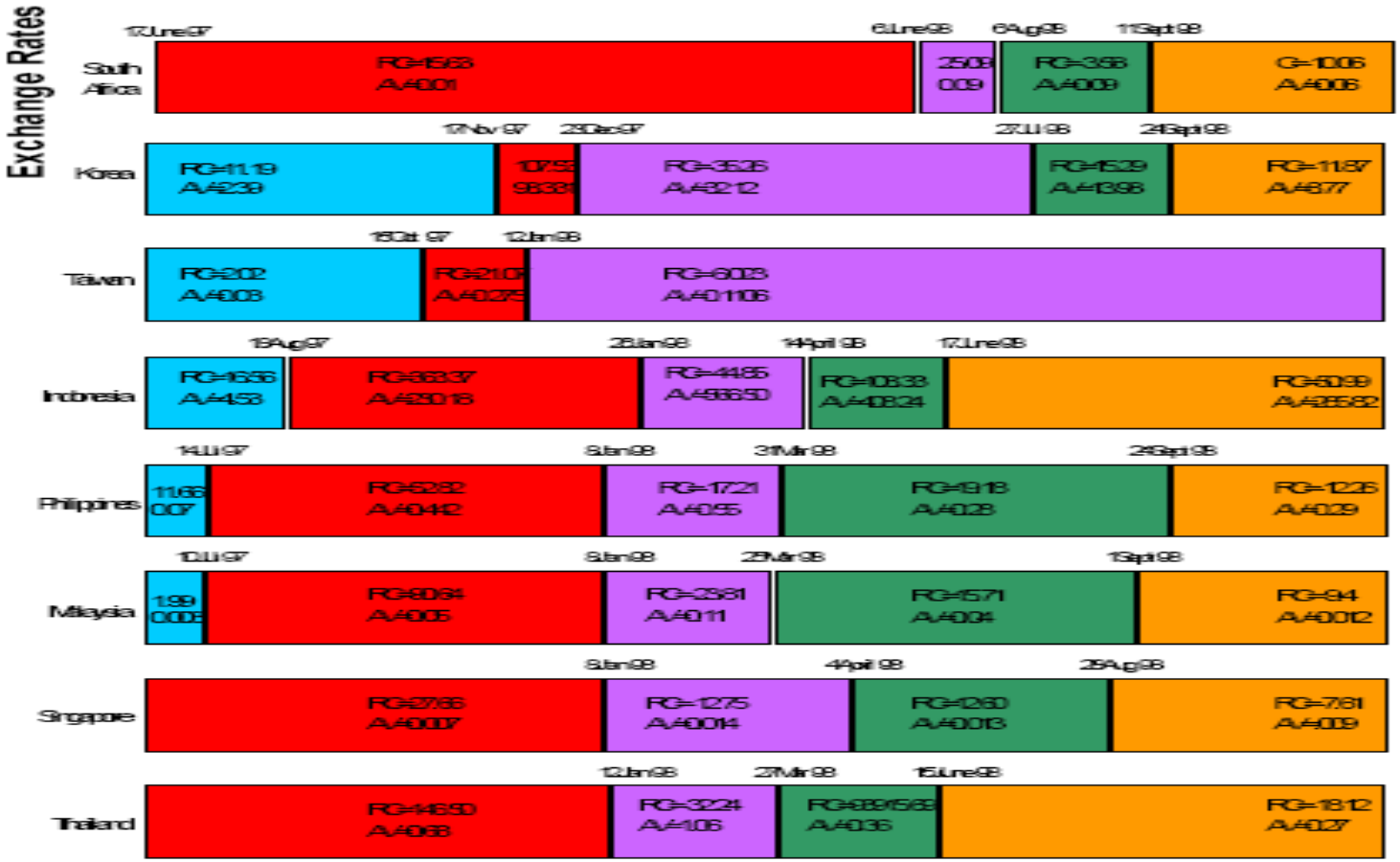
Test Allowing for Simultaneity

- This suggests an alternative test on the nature of the propagation mechanism of financial crises:
- Let $\phi = \frac{cov(x_t, y_t)}{cov\left(x_t^h, y_t^h\right)}$, $\theta = \left(\frac{var\left(x_t^h\right)}{\sigma_x^2} \cdot \frac{var\left(y_t^h\right)}{\sigma_y^2}\right)$.
- Shift Contagion: $\phi < \theta$, the implication is that the crisis is being propagated through the interdependence of markets (through common "fundamentals", or through simultaneity), increasing the comovement of market indicators.
- Pure Contagion: $\phi > \theta$, the implication is that the crisis has its source in a shock to a single "originator" country, decreasing the comovement of markets.

The Data

- East Asian financial crisis: 1997-98.
- 11 Countries: Singapore; Thailand; Malaysia; Philippines; Indonesia; Taiwan; S.Korea; Hong Kong; Brazil; South Africa; Russia.
- Frequency: daily
- Series: exchange rate; stock market index.


Stock Exchange
Russia
6Feb 96
22Oct 97
24April 98
21Aug 98
RC= 1103.37
AV= 15.06
RC= -36.97
AV= 41.75
RC= -66.46
AV= 36.65
RC= 124.43
AV= 49.66
South Africa
7Jul 97
12Dec 97
22April 98
11Sept 98
RC= 10.003
AV= 40.02
RC= -26.49
AV= 77.20
48.49
91.38
RC= -43.50
AV= 116.79
RC= 15.65
AV= 88.16
Taiwan
4Aug 97
13Jan 98
27Feb 98
RC= 5429.32
AV= 74.36
RC= -36.27
AV= 140.29
RC= 24.9066
AV= 132.679
RC= -30.09
AV= 108.86
Indonesia
9Jul 97
12Dec 98
30Mar 98
22Sept 98
RC= -1.73
AV= 10.87
RC= -53.70
AV=13.35
RC= 58.06
AV= 17.12
RC= -52.63
AV= 9.98
54.47
9.49
Brazil
8Jul 97
12Nov 97
15April 98
10Sept 98
27Nov 98
RC= 154.33
AV= 99.33
RC= -42.56
AV= 381.44
RC= 57.24
AV= 205.29
RC=61.29
AV=264.29
91.01
313.30
Hong Kong
7Aug 97
12Jan 98
30Mar 98
14Aug 98
RC= 45.45
AV= 123.46
RC= -50.75
AV= 344.99
44.06
304.119
RC= -43.62
AV= 192.52
RC= 54.33
AV= 224.49
Korea
17June 97
12Dec 98
2Mar 98
16June 98
RC= 11.22
AV= 6.65
RC= -55.74
AV= 11.76
63.76
17.66
-51.25
11.34
RC= 100.68
AV= 9.34
Malaysia
26Feb 97
13Jan 98
2Mar 98
2Sept 98
RC= 17.64
AV= 7.54
RC= -62.41
AV= 18.22
RC=66.82
AV=25.99
RC= -63.67
AV= 12.01
Phillippines
4Feb 97
12Jan 98
26Mar 98
14Sept 98
RC= 18.57
AV= 28.23
RC= -56.19
AV= 40.86
53.02
54.15
RC= 63.36
AV= 33.05
RC= 78.99
AV= 43.19
Thailand
20Feb 96
13Jan 98
4Feb 98
7Sept 98
RC=-1.73
AV=10.87
RC=75.54
AV=13.885
RC=64.79
AV=20.14
RC=62.91
AV=6.80
69.70
9.14
Singapore
22Oct 96
18Feb 97
4Sept 98
RC=17.38
AV=3.91
13.43
3.36
RC=55.95
AV=6.90
54.33
224.49


Exchange Rates
South Africa
Korea
Taiwan
Indonesia
Philippines
Malaysia
Singapore
Thailand

Principal Features:

- The most often cited feature of the 1997-98 financial crisis: exchange rate depreciations.
- BUT: equity markets of countries affected by the crisis in all instances showed signs of the emerging crisis well in advance of any currency depreciations.
- For most countries we note the presence of four phases, with two sharp declines, and two periods of recovery.

Correlation Measures: Chg. for Exch Rate - 17/6/97

	Thai.	Mal.	Ind.	HK.	Sin.	Phil.	Taiw.	S.Kor.	Braz.	S. Af.	Rus.
Mal.	0.52										
Ind.	-0.07	1.38									
HK.	-0.37	-0.38	-0.18								
Sin.	0.37	0.16	1.42	-0.45							
Phil.	0.98	0.91	0.62	0.56	1.19						
Taiw.	0.62	0.87	0.12	0.19	1.12	0.62					
S.Kor.	0.94	1.46	0.00	1.05	1.49	0.47	0.68				
Braz.	0.40	0.62	1.16	0.62	0.75	0.61	0.76	0.38			
S. Af.	0.40	1.32	-0.13	0.98	1.58	0.51	0.29	-0.42	0.77		
Rus.	-0.61	0.85	-0.79	-0.44	0.03	-0.46	-0.42	-0.80	-0.27	-0.34	
Avg	0.32	0.77	0.35	0.15	0.77	0.60	0.48	0.52	0.58	0.50	-0.32

Table: Change in Exchange Rate Correlations

Correlation Measures: Chg. for Equity - 6/2/97

	Thai.	Mal.	Ind.	HK.	Sin.	Phil.	Tai.	S.Kor.	Braz.	S.Afr.	Rus.
Mal.	-0.14										
Ind.	-0.03	0.37									
HK.	-0.58	-0.27	0.46								
Sin.	-0.04	-0.01	0.25	-0.27							
Phil.	-0.10	-0.01	0.43	-0.38	-0.01						
Tai.	-0.81	-0.38	-0.36	0.46	-0.58	-0.40					
S.Kor.	0.08	0.09	0.17	-0.07	0.14	0.08	-0.82				
Braz.	-1.41	-1.09	-0.35	-0.38	-1.04	-1.13	0.73	-1.19			
S.Afr.	-0.65	-0.51	0.19	-0.39	-0.51	-0.49	0.25	-0.52	-0.42		
Rus.	-0.74	-0.4	-0.38	0.26	-0.59	-0.49	1.11	-0.51	0.75	0.28	
Avg.	-0.44	-0.24	0.08	-0.12	-0.26	-0.25	-0.28	-0.08	-0.55	-0.28	-0.07

Table: Equity Markets

Inference from Correlations:

- The exchange rate evidence suggests an increase in cross-market correlation, and hence of the presence of crisis propagation (with the exception of Russia).
- The equity market evidence does not provide strong support for cross-market propagation of the financial crisis in the case of equity markets (with the possible exception of Indonesia and South Korea).

Long Run Equil.: Bounds Test Exch Rate pre 17/6/97

	Thai.	Mal.	Ind.	HK.	Sin.	Phil.	Tai.	S.Kor.	Braz.	S.Afr.	Rus.
Thai.		2.00	10.12*	4.60	2.48	3.54	1.05	5.49	7.89*	0.43	1.63
Mal.	9.13*		8.48*	5.80*	4.13	3.29	2.86	0.19	8.78*	0.02	2.37
Ind.	3.78	4.49		6.33*	6.31*	4.19	2.99	3.90	4.89*	1.22	2.96
HK.	8.94*	2.25	8.84*		5.27	3.59	1.15	1.99	8.26*	0.13	1.68
Sin.	10.00*	5.35	8.66*	5.37		3.02	1.16	0.17	7.84*	0.63	3.82
Phil.	8.47*	1.65	8.36*	4.51	2.71		1.71	0.18	8.82*	0.25	1.64
Tai.	8.50*	6.25*	8.84*	4.75	2.46	6.03*		1.23	7.81*	0.07	2.24
S.Kor.	10.75*	2.31	10.73*	7.10*	2.54	3.29	1.01		8.02*	0.03	3.11
Braz.	8.71*	1.71	8.68*	4.84	3.30	3.69	1.02	0.57		0.14	2.55
S.Afr.	8.85*	2.65	10.15*	5.44	3.09	3.21	1.70	2.91	7.84*		3.67
Rus.	5.77*	2.07	2.44	2.67	3.50	6.71*	5.40	3.62	3.55	1.46	

Table: Bounds Tests

Long Run Equil.: Bounds Test Exch Rate post 17/6/97

	Thai.	Mal.	Ind.	HK.	Sin.	Phil.	Tai.	S.Kor.	Braz.	S.Afr.	Rus.
Thai.		1.43	2.20	3.57	1.47	1.81	1.56	3.41	0.04	0.74	0.86
Mal.	3.42		2.47	3.70	3.58	5.08	3.49	2.36	0.16	1.22	1.28
Ind.	4.27	2.44		5.00	1.93	2.78	1.68	1.60	0.15	4.53	1.28
HK.	3.47	2.21	1.37		2.18	3.52	1.73	4.32	0.07	0.61	1.08
Sin.	3.32	2.01	1.73	3.44		8.34*	1.48	1.91	0.18	1.21	2.83
Phil.	3.58	2.29	1.87	3.30	2.21		2.05	1.31	0.32	0.73	1.88
Tai.	3.36	3.31	4.23	5.13	3.33	6.04*		2.64	0.65	1.78	2.11
S.Kor.	4.35	2.38	2.93	2.47	2.32	2.63	1.63		0.04	1.21	0.96
Braz.	4.31	2.26	1.23	4.28	2.36	2.73	1.79	1.26		0.98	2.66
S.Afr.	3.76	2.33	1.69	4.27	2.30	2.84	1.91	1.25	0.44		4.84
Rus.	4.19	1.72	1.96	3.67	1.93	3.73	2.68	1.45	0.05	2.69	

Table: Bounds tests

Long Run Equil.: Bounds Test Equity pre 6/2/97

	Thai.	Mal.	Ind.	HK.	Sin.	Phil.	Tai.	S.Kor.	Braz.	S.Afr.	Rus.
Thai.		0.64	1.30	0.24	81.33*	0.21	4.91	6.15*	3.97	1.53	6.08*
Mal.	6.52*		1.96	0.13	92.03*	4.59	4.90	8.93*	6.74*	3.01	7.53*
Ind.	0.82	0.67		0.47	31.92*	0.95	6.61*	0.89	1.51	0.61	5.37
HK.	3.87	4.01	1.61		63.29*	6.68*	4.74	5.48	6.14*	4.53	5.35
Sin.	0.67	0.62	0.76	0.23		0.25	4.16	2.48	4.67	1.34	5.18
Phil.	5.65	5.48	1.65	0.12	76.79*		4.95	7.49*	6.35*	2.40	5.94*
Tai.	0.82	0.76	6.01*	0.62	23.72*	0.92		1.49	0.68	0.83	4.35
S.Kor.	0.84	0.63	1.69	0.83	48.03*	0.32	6.52*		1.01	0.97	4.66
Braz.	2.15	0.91	0.94	0.18	37.58*	0.81	5.56	3.53		0.38	4.60
S.Afr.	2.03	0.83	1.42	0.14	58.72*	0.74	5.47	3.28	11.94*		5.20
Rus.	3.20	2.64	0.61	0.69	0.92	2.26	3.27	1.27	3.47	1.38	

Table: Bounds Test

Long Run Equil.: Bounds Test Equity post 6/2/97

	Thai.	Mal.	Ind.	HK.	Sin.	Phil.	Tai.	S.Kor.	Braz.	S.Afr.	Rus.
Thai.		1.35	0.54	1.33	1.91	1.48	2.66	1.14	1.32	1.54	1.01
Mal.	11.76*		6.22*	3.43	2.10	2.88	3.24	0.94	2.03	3.16	2.60
Ind.	15.68*	2.44		2.59	0.97	1.53	4.14	1.00	1.90	2.87	3.96
HK.	5.66	1.84	0.58		1.17	1.07	2.98	1.18	2.94	3.03	8.93*
Sin.	18.10*	0.69	2.19	1.55		2.04	2.99	0.93	1.93	2.59	2.16
Phil.	12.20*	0.48	3.72	1.99	1.17		3.07	0.91	1.98	2.41	1.94
Tai.	7.19*	5.72	1.61	1.33	2.96	3.98		2.34	9.81*	1.40	7.17*
S.Kor.	21.37*	2.29	2.08	2.83	5.56	2.28	2.70		1.83	3.01	2.42
Braz.	7.13*	7.20*	1.90	2.47	4.65	5.97*	3.56	2.87		1.10	2.23
S.Afr.	5.14	6.51*	1.44	2.60	4.64	5.24	2.55	5.00	1.46		1.09
Rus.	7.23*	4.33	2.47	2.91	2.14	2.60	2.21	2.87	1.43	1.25	

Table: Bounds Test

Inference from Bounds Tests:

- Exchange rates: the crisis did precipitate a structural break in cross market associations between rates; the cause of the break remains unspecified.
- Equity markets: the financial crisis of 1997-99 did have an impact on the structure of cross market associations.

Rigobon Test: Exch Rate - Ratio of Variances

- Column: target countries; Row:progenitor countries

	Thai.	Mal.	Ind.	HK.	Sin.	Phil.	Tai.	S.Kor.	Braz.	S.Afr.	Rus.
Thai.		1.17	1.17		0.67	1.01	0.97	1.20		0.61	
Mal.			1.09			0.85	0.86	1.10		0.57	
Ind.							0.73	0.99		0.54	
HK.											
Sin.	1.50	1.76	1.76			1.52	1.45	1.80		0.91	
Phil.			1.29				1.01	1.30		0.67	
Tai.								1.73		1.14	
S.Kor.										0.81	
Braz.											
S.Afr.											
Rus											

Rigobon Test: Equity - Ratio of Variances

- Column: target countries; Row:progenitor countries

	Thai.	Mal.	Ind.	HK.	Sin.	Philip.	Tai.	S.Kor.	Braz.	S.Afr.	Rus.
Thai.		1.20	0.94	0.63		0.79	0.64	1.07	0.59	0.44	0.94
Mal.			0.98	0.71			0.45	0.83	0.44	0.51	0.72
Ind.				0.87			0.61		0.58	0.69	0.97
HK.											1.31
Sin.	0.92	1.08	0.84	0.57		0.71	0.59	0.97	0.53	0.39	0.86
Philip.		1.60	1.53	1.08			0.68	1.28	0.67	0.77	1.11
Tai.				1.38							1.71
S.Kor.			1.12	0.91			0.63		0.61	0.70	0.98
Braz.			1.73	1.50			1.06			1.19	1.68
S.Afr.			1.46	1.27			0.89		0.84		1.41
Rus.											

Inference from Rigobon:

- Exchange rate evidence:
  - For the East Asian countries the variance ratio is almost uniformly >1, suggesting that the crisis gained in volatility as it propagated across markets. For the Asian markets: “shift” not "pure" contagion.
  - South Africa: less than proportional impact on the variance of the South African exchange rate (exception Taiwan). "Pure" contagion.
- Equity market evidence:
  - mixed - more evidence favouring “pure” contagion.
  - For South Africa, Taiwan and Brazil: "pure” contagion on asset markets is at least plausible.
  - For others, notably Malaysia: “shift” contagion.
  - Other countries: evidence mixed; at least some "shift" rather than "pure" contagion.

Exchange Rate: phi-theta test

- θ values above diagonal; ϕ values below diagonal

	Thai.	Sin.	Mal.	Phil.	Ind.	Tai.	S.Kor.	S.Afr.
Thai.		1.51	0.86	0.99	0.86	1.04	0.84	1.65
Sin.	0.40		1.29	1.49	1.29	1.56	1.26	2.48
Mal.	0.97	0.50		1.05	0.82	1.047	0.81	1.58
Phil.	1.23	0.20	1.06		0.98	1.26	0.97	1.88
Ind.	1.64	1.03	1.23	1.33		1.15	0.84	1.55
Tai.	1.31	0.22	1.050	1.27	1.45		2.26	3.44
S.Kor.	0.96	0.09	0.91	1.15	1.53	4.85		2.54
S.Afr.	4.40	-1.32	1.59	1.96	1.41	4.14	-4.61	

Table: Exchange Rate

Exchange Rate: phi-theta test

- Column: target countries; Row:progenitor countries

	Thai.	Mal.	Ind.	Sin.	Phil.	Tai.	S.Kor.	S.Afr.
Thai.		$\phi > \theta$	$\phi > \theta$	$\phi < \theta$	$\phi > \theta$	$\phi > \theta$	$\phi > \theta$	$\phi > \theta$
Mal.			$\phi > \theta$		$\phi > \theta$	$\phi > \theta$	$\phi > \theta$	$\phi > \theta$
Ind.						$\phi > \theta$	$\phi > \theta$	$\phi < \theta$
Sin.	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$		$\phi < \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$
Phil.			$\phi > \theta$			$\phi > \theta$	$\phi > \theta$	$\phi > \theta$
Tai.							$\phi > \theta$	$\phi > \theta$
S.Kor.								$\phi < \theta$

Table: Exchange Rate: phi-theta test

Equity Markets: phi-theta test

- θ values above diagonal; ϕ values below diagonal

	Sin.	Thai.	Phil.	Mal.	S.Kor.	S.Afr.	Braz.	Ind.	Tai.	HK.
Sin.		0.88	1.14	0.75	0.84	2.07	1.52	0.96	1.38	1.43
Thai.	0.8		1.26	0.83	0.93	2.28	1.7	1.06	1.56	1.58
Phil.	1.06	0.81		1.33	1.66	2.74	3.15	1.38	3.1	1.96
Mal.	0.75	0.7	1.31		1.08	1.75	2.03	0.91	2	1.26
S.Kor.	0.69	0.91	1.03	0.82		2.11	2.43	1.32	2.35	1.62
S.Afr.	2.74	0.27	3.66	1.97	0.43		3.54	2.04	3.33	2.35
Braz.	-0.65	0.86	3.99	1.29	-0.76	3.82		2.43	3.96	2.8
Ind.	0.72	0.52	0.97	0.68	0.61	1.76	1.55		2.29	1.62
Tai.	-0.39	0.73	1.45	0.41	-0.07	2.38	3.12	1.36		3.06
HK.	1.38	0.66	2.25	1.09	0.28	4.45	3.47	1.24	1.61	

Table: Stock Market

Equity Markets: phi-theta test

- Column: target countries; Row:progenitor countries

	Sin.	Thai.	Phil.	Mal.	S.Kor.	S.Afr.	Braz.	Ind.	Tai.	HK.
Sin.		$\phi < \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$	$\phi > \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$
Thai.			$\phi < \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$
Phil.				$\phi < \theta$	$\phi < \theta$	$\phi > \theta$	$\phi > \theta$	$\phi < \theta$	$\phi < \theta$	$\phi > \theta$
Mal.					$\phi < \theta$	$\phi > \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$
S.Kor.						$\phi < \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$
S.Afr.							$\phi > \theta$	$\phi < \theta$	$\phi < \theta$	$\phi > \theta$
Braz.								$\phi < \theta$	$\phi < \theta$	$\phi > \theta$
Ind.									$\phi < \theta$	$\phi < \theta$
Tai.										$\phi < \theta$
HK.										

Table: Stock Market: phi-theta test

Inference: phi-theta test

- Exchange rate:
  - "Pure" contagion effects between countries were present,
  - Exceptions: for the transmission of the crisis from Singapore, and from Thailand to Singapore, Indonesia to South Africa, and South Korea to South Africa.
- Equity Markets:
  - Reject "pure" contagion in favour of "shift" contagion.
  - Exceptions: South Africa, Brazil, and the Hang Seng indexes, where may have been some "pure" contagion.

Conclusions I: generic

- The 1997-99 crisis was mixed in character, with evidence of both shift and pure contagion emerging from the empirical tests.
- The nature of the contagion differs between countries, between exchange rate and equity markets, and also depends crucially on whether simultaneity is assumed present or absent between markets.

Conclusions II: without simultaneity

- Over the 1997-9 period:
  - East Asia was characterized predominantly by shift contagion for exchange rates and equity markets,
  - while only South Africa faced pure contagion for its exchange rate,
  - and South Africa, Brazil and Taiwan faced pure contagion in their equity markets.

Conclusions III: with simultaneity

- Over the 1997-9 period:
  - all countries included in the study faced pure contagion in exchange rate markets,
  - while in equity markets all countries faced shift contagion except South Africa, Brazil and Hong Kong for whom the evidence favours pure contagion.

Conclusions IV: policy implications

- Differential policy responses appropriate?
- Where **Shift**: none, since relative price adjustment
- Where **Pure**: more proactive, since noise transmission