

Measuring Contagion under Simultaneity

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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
- Empirical Results:
 - Rigobon; variance ratio
 - $\phi - \theta$ test
- Conclusions

Priors in the Literature

- "Shift" contagion: fundamentals: trade; similar initial conditions; financial linkages
- "Pure" contagion: no fundamentals; investor perception alone.
- 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)
- Rigobon (1999), Forbes et al. (2001), Forbes and Rigobon (2005)

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:

$$y_t = \beta x_t + \varepsilon_t \quad (1)$$

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:
 $\text{var}(\eta_t^h) > \text{var}(\eta_t^l)$,
- 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 $\text{plim}\beta^h = \text{plim}\beta^l$.

- Since $\text{var}(x_t^h) > \text{var}(x_t^l)$, for consistent β^l 's,
 $\text{cov}(x_t^h, y_t^h) > \text{cov}(x_t^l, y_t^l)$, and by the same proportion as for
 $\text{var}(x_t)$.

Background

- The original formulation of the problem:
 - $\text{var}(y_t)$ is homogeneous of degree one on $\text{var}(x_t)$ and $\text{var}(\varepsilon_t)$,
 - $\partial \text{var}(x_t) / \partial t > 0$, but $\partial \beta^i / \partial t = \partial \text{var}(\varepsilon_t) / \partial t = 0$ over the two samples,
 - $\implies \partial \text{var}(y_t) / \partial t < \partial \text{var}(x_t) / \partial t$,
 - $\implies \partial \text{var}(y_t) / \partial t < \partial \text{cov}(x_t, y_t) / \partial t$
 - \implies 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:

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

where $\text{var} \left(x_t^h \right)$ 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.

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

$$\text{var} \left(y_t^h \right) = \left(1 + \delta_t \rho^2 \right) \sigma_y^2$$

$$\rho_t^h = \rho \left[\frac{1 + \delta_t}{1 + \delta_t \rho^2} \right]^{\frac{1}{2}}$$

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):

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

- First test of non-fundamentals (pure contagion) led explanation of contagion

- Supposition: $\frac{\text{var}(x_t^h)}{\sigma_x^2} > \frac{\text{var}(y_t^h)}{\sigma_y^2}$.

- Satisfied: $\left[\frac{\text{var}(x_t^h)}{\sigma_x^2} \cdot \frac{\sigma_y^2}{\text{var}(y_t^h)} \right]^{-\frac{1}{2}} < 1$,

- Violated: $\left[\frac{\text{var}(x_t^h)}{\sigma_x^2} \cdot \frac{\sigma_y^2}{\text{var}(y_t^h)} \right]^{-\frac{1}{2}} > 1$.

The Problem of this Paper

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

$$y_t = \beta z_t + \varepsilon_t$$

$$x_t = z_t + \eta_t$$

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.
- $\implies E[\eta_t \varepsilon_t] = 0, E[\varepsilon_t \varepsilon_t'] = \sigma_\varepsilon^2, E[\eta_t \eta_t'] = \sigma_\eta^2$ condition is violated.

Test Allowing for Simultaneity

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

$$\text{var}(x_t^h) = (1 + \delta_z) \sigma_z^2 + (1 + \delta_\eta) \sigma_\eta^2$$

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

- Then:

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

Test Allowing for Simultaneity

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

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

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

Test Allowing for Simultaneity

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

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

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

Test Allowing for Simultaneity

- Note that:

$$\delta_z \rightarrow 0, \rho^h < \rho$$

$$\delta_\eta \rightarrow 0, \rho^h > \rho$$

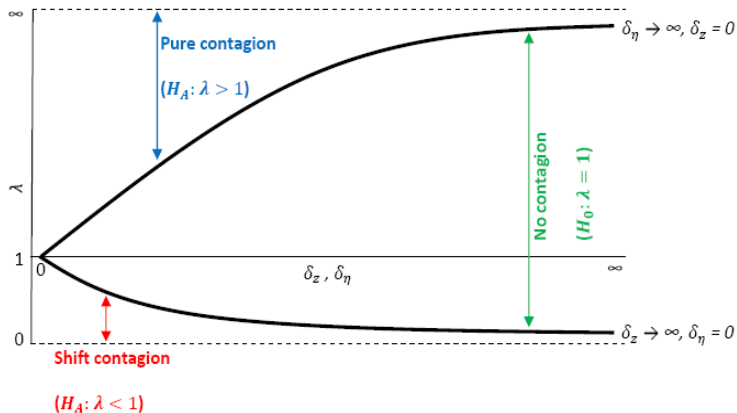
- Hence:

- $\lambda > 1 \Rightarrow \delta_z \rightarrow 0, \implies$ shock to the system emerges through η_t not z_t .
- $\lambda < 1 \Rightarrow \delta_\eta \rightarrow 0, \implies$ 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 $\phi = \frac{\text{cov}(x_t, y_t)}{\text{cov}(x_t^h, y_t^h)}$, $\theta = \left(\frac{\text{var}(x_t^h)}{\sigma_x^2} \cdot \frac{\text{var}(y_t^h)}{\sigma_y^2} \right)$.
- 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.

Illustration:



Statistical Properties of the Test

- Monte Carlo simulations
- Under the null, $\lambda = 1$, $\implies \phi = \theta$, no contagion under either definition.
- Two one-tailed tests:
 - $\lambda < 1$, $\implies \phi < \theta$, for shift contagion
 - $\lambda > 1$, $\implies \phi > \theta$, for pure contagion
- Monte Carlo simulations under two alternative distributional assumptions:
 - $\varepsilon_t \sim N(0, 1)$, $\eta_t \sim N(0, 1)$.
 - $\ln \varepsilon_t \sim N(0, 1)$, $\ln \eta_t \sim N(0, 1)$.

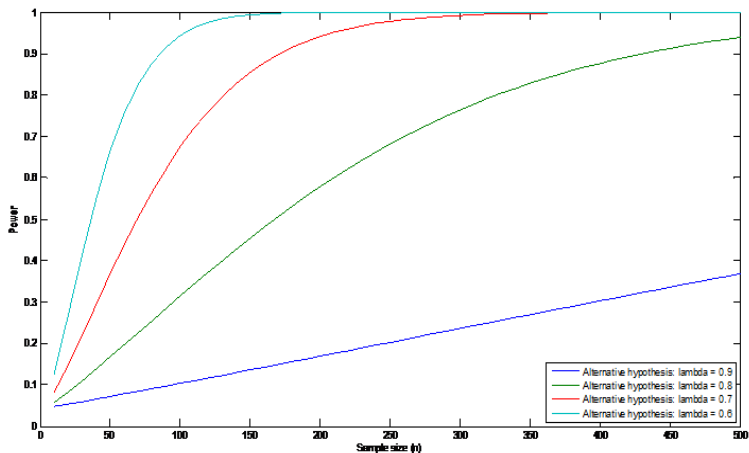
Statistical Properties of the Test

- Critical values conditional on:
 - $\beta, \delta_z, \delta_\eta$
- Power:
 - Probability that the test will reject a false null,
 - i.e. test will not make a Type II error.
- Size:
 - Probability of false positive (reject null when true),
 - i.e. test will make a Type I error.

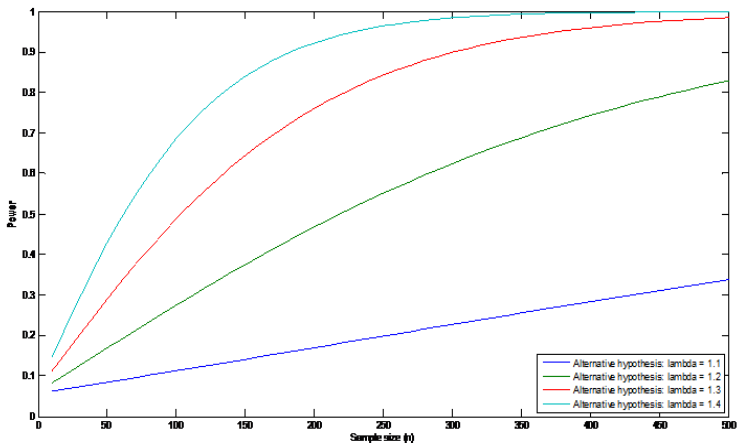
Critical Values

Panel A: $\beta = 0.1$						
$\delta_z \rightarrow$		0.1	0.5	1	1.5	2
$\alpha \downarrow$						
n = 100	15	0.941	0.777	0.656	0.579	0.525
	10	0.943	0.783	0.665	0.590	0.535
	5	0.946	0.793	0.678	0.605	0.550
	1	0.951	0.811	0.704	0.635	0.584
n = 200	15	0.939	0.770	0.648	0.570	0.514
	10	0.941	0.776	0.655	0.579	0.523
	5	0.943	0.784	0.666	0.591	0.535
	1	0.948	0.800	0.688	0.619	0.562
n = 300	15	0.938	0.767	0.644	0.565	0.509
	10	0.940	0.772	0.651	0.572	0.517
	5	0.942	0.780	0.660	0.583	0.529
	1	0.946	0.794	0.683	0.606	0.555
n = 400	15	0.937	0.766	0.641	0.562	0.506
	10	0.939	0.770	0.647	0.568	0.513
	5	0.941	0.777	0.657	0.579	0.524
	1	0.945	0.792	0.676	0.602	0.549
n = 500	15	0.937	0.765	0.640	0.559	0.503
	10	0.938	0.769	0.645	0.566	0.510
	5	0.940	0.775	0.654	0.577	0.520
	1	0.945	0.789	0.673	0.597	0.543

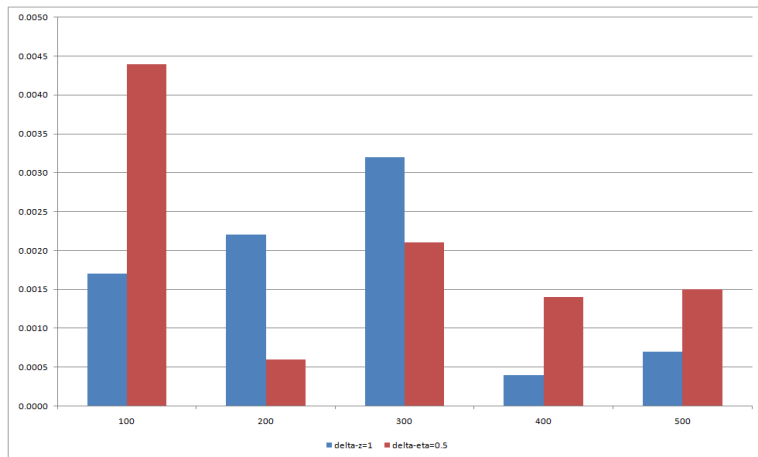
Power Characteristics of the Test: Normal



Power Characteristics of the Test: Log-Normal

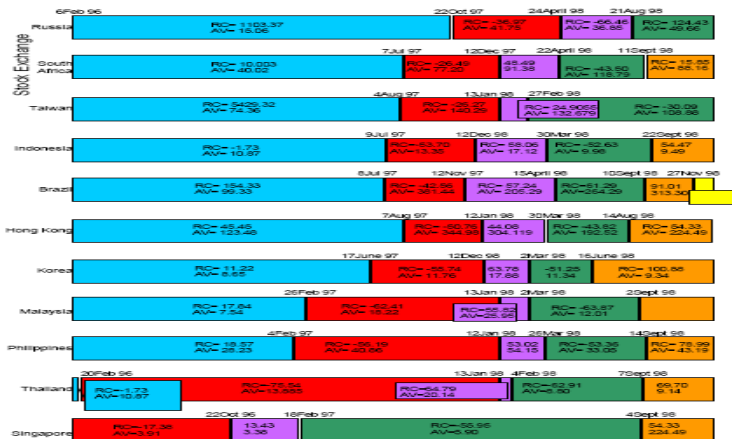


■ Under $\beta = 1$



The Data

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



Rigobon Variance Ratio Test: Stock Market Returns

- Column: target countries; Row: progenitor countries

	Thailand	Philippines	Malaysia	S. Korea	South Africa	Brazil	Indonesia	Taiwan	Hong Kong	Russia
Singapore	6.98	4.56	5.78	5.41	5.00	2.63	5.90	2.88	5.22	3.72
Thailand		0.65	0.83	0.77	0.72	0.38	0.84	0.41	0.75	0.53
Philippines			1.27	1.19	1.10	0.58	1.29	0.63	1.15	0.82
Malaysia				0.94	0.87	0.45	1.02	0.50	0.90	0.64
S. Korea					0.92	0.49	1.09	0.53	0.97	0.69
South Africa						0.52	1.18	0.58	1.04	0.74
Brazil					1.91		2.25	1.10	1.99	1.42
Indonesia					0.85	0.45		0.49	0.89	0.63
Taiwan									1.82	1.29
Hong Kong										0.71

Inference from Rigobon:

- Equity market evidence:
 - 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.

Equity Markets: phi-theta test

- θ values above diagonal; ϕ values below diagonal

	Singapore	Thailand	Philippines	Malaysia	S. Korea	South Africa	Brazil	Indonesia	Taiwan	Hong Kong
Singapore		0.70	0.74	0.74	0.65	0.74	0.78	0.69	0.70	0.73
Thailand	29.07		0.71	0.73	0.78	0.70	0.15	0.68	0.79	0.80
Philippines	159.67	0.07		0.78	0.70	0.77	1.03	0.73	0.68	0.72
Malaysia	62.14	0.03	0.14		0.68	0.71	0.47	0.71	0.71	0.77
S. Korea	80.73	0.03	0.19	0.07		0.66	0.63	0.76	0.65	0.66
South Africa	110.30	0.05	0.25	0.10	0.13		0.74	1.19	0.64	0.68
Brazil	1454.34	0.61	3.36	1.31	1.70	2.32		0.51	0.72	0.94
Indonesia	57.11	0.02	0.13	0.05	0.07	0.09	1.20		0.56	0.78
Taiwan	1008.63	0.42	2.33	0.91	1.18	1.61	21.22	0.83		0.74
Hong Kong	92.77	0.04	0.21	0.08	0.11	0.15	1.95	0.08	1.35	



Equity Markets: phi-theta test

- Column: target countries; Row: progenitor countries

	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

Significance:

	Thailand	Philippines	Malaysia	S.Korea	South Africa	Brazil	Indonesia	Taiwan	Hong Kong
Singapore	0.716	0.139	0.246	0.361	0.260	0.434	0.165	0.072	0.159
Thailand		0.987	1.379	2.788	1.052	1.611	0.973	1.944	1.431
Philippines			0.909	0.723	0.697	-1.420	0.761	0.710	0.689
Malaysia				1.149	1.398	-0.284	0.870	0.838	0.946
S.Korea					0.644	0.524	1.058	0.577	0.609
South Africa						0.344	1.860	0.583	0.627
Brazil							0.529	0.512	0.385
Indonesia								0.735	0.937
Taiwan									0.469

Inference: phi-theta test

- Equity Markets:
 - the propagation of the crisis *from* Singapore and Brazil, and
 - the impact of the crisis *on* Brazil and Taiwan satisfies the condition for “pure” contagion,
 - for the rest, the evidence favours the presence of “shift” 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, and depends 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 equity market returns,
 - while only South Africa, Brazil and Taiwan faced pure contagion in their equity markets.

Conclusions III: with simultaneity

- Over the 1997-9 period:
 - Equity Markets:
 - the propagation of the crisis *from* Singapore and Brazil, and
 - the impact of the crisis *on* Brazil and Taiwan satisfies the condition for “pure” contagion,
 - for the rest, the evidence favours the presence of “shift” contagion.

Conclusions IV: a further puzzle

- What if BOTH forms of contagion are present?

