CS4-G1

The 12th International Convention of

the *East Asian Economic Association*

LG Convention Hall, International Education Building,

Ewha Womans University, Seoul, 2-3 October 2010

Convention Theme: "Asia and the Global Economic Recovery"

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Capturing Long-Tailed Black Swan Risk in East Asian Currencies

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September 2010

Abstract

The Global Financial Crisis of 2008 and the Asian Financial Crisis of 1997/1998 are two events that share a common characteristic. Both can be seen as a network crisis, though one is global and the other is regional. The world or region is currently highly inter-connected and inter-dependent through trade, finance and telecommunication networks that transfer information and property rights that shape behaviour across networks. This can be illustrated through behaviour in highly complex and deep financial markets, such as behaviour in currency markets arising from contagion and inter-action between market forces that create unexpected risks. This paper introduces a Phasor method to capture the often ignored long-tailed black swan risk, also known as rare events. Using the *augmented network theory* (Sheng, Kwek, Cho, 2009), based on principles of engineering and physics, we model the market movements caused by the confluence of different market forces, by transforming the market movements (x,y) into sinusoidal waves ($\cos\theta$, $\sin\theta$). In particular, when the two forces collide ($\cos\theta = \sin\theta$), they create directions that are not always predictable, though the amplitude of the sine waves and the cosine waves are predictable. To demonstrate this network effect, nine currencies, *i.e.* the Indonesian Rupiah, Chinese Renminbi, Hong Kong dollar, Korean Won, Japanese Yen, Malaysian Ringgit, Philippines Peso, Singapore dollar, and Thai Baht are modeled through the Phasor theory in the currency markets. The results of the study do show that we are able to capture these rare events. While not all directional changes are predictable due to lack of contextual information that we may not be able to capture, there are certain patterns of behaviour that conform with tools common in engineering and physics.

Key words: *Network-Phasors, Feedback Mechanism, Policy-Space*

JEL: C45, E61, F3, F36
*corresponding author
(Session I or J)

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1. Introduction

A common concept shared between economics, and engineering and mathematics is the concept of stable states. It is about a system gravitating towards equilibrium points, and mathematically is also known as eigenstates or eigenfunctions. However, such states are often difficult to achieve. Especially in economics, there always exists opposing and asymmetric forces that influence the gravitation of the point towards equilibrium. If the overall feedback of the system is negative, then the system will tend to be stable. This rarely happens. If overall feedback of the system is positive, the system will result in a runaway situation. In particular in rare events, like an unpredictable pertubation, it can cause the positive feedback to result in excessive high amplification of these signals. These rare events are caused by speculative attacks that can distress the financial markets, leading to disorderly markets and systemic risks.

Such targeted or speculative attacks are associated with long-tailed networks. One of the features found in long-tailed networks is that the rare event has a major impact. For example, the Iceland's Eyjafjallajokull volcanic incident of April 13, 2010, the Global Financial Crisis (GFC) of 2007/2009, and the Asian Financial Crisis (AFC) of 1997/98 (triggered by the financial collapse of the Thai baht), have one common feature: a single event that spewed-out into widespread global or regional fallouts, affecting a wider network of networks (*e.g.* from airlines to rail lines, from housing market to financial markets) with a display of feedback mechanisms seen in network behavior (Allen and Gale, 2000).

There has been no comprehensive study on capturing targeted attacks using network theory. Here, we report the existence of an alternating feedback mechanism in currency markets using a network-phasor model for the purpose of capturing targeted attacks. We show that economic systems also display behavioral patterns of a network effect based on principles common to engineering and physics. This study adds to a line of new thinking to model financial network risk (Anderson (2006), Beinhocker (2005), Taleb (2007), Soros (1987)). Bankers and financial economists are now working with mathematical biologists to learn lessons about resilience from natural ecosystems. Bank of England's Haldane (2009) has begun to look at the banking regulatory structure as one biological "complex adaptive system" (Cookson, Tett, and Cook (2009), May, Levin, and Sugihara (2008)).

This study also advances Barabasi's (1999, 2002) scale-free networks to currency and financial markets by characterizing financial risks as systemic and having 'small-world' property with fat-tailed network characteristics[1]. In particular, economic systems that displays small-world network and fat-tailed network characteristics are vulnerable to targeted/speculative attacks, known as 'Black Swan risk' (Watts (2003), Anderson (2006), Taleb (2007), Newman (2003)). Black Swans (Taleb, 2007) are defined as an event with three attributes (a) rarity, (b) extreme impact, and (c) retrospective predictability.

In particular, we show that when targeted attacks strike at a node with the weakest link, the impact may destroy its original structure. New policy measures are instituted, and often time, this new structure may adopt an exact opposite feature. For example, in the exchange rate regimes, a country that adopts a floating regime in pre-crisis, may switch to a fixed rate regime in the post-crisis, like the Thai Baht. However, nodes with stronger links (with deep financial markets) can absorb these long-tailed shocks better than those with weaker links, like the Singaporean dollar.

This paper examines the network effect of systemic risks which are characterized by long-tailed network and 'small-world' property in exchange rate systems. Section 2 discusses the connectivity characteristics in financial networks. Section 3 introduces a dynamic phasor model to capture the long-tailed network characteristics due to exchange rate distortions. Section 4 give the empirical feedback mechanism in the network-phasors. Section 5 examines the policy-space in the network-phasors. Section 6 concludes the study.

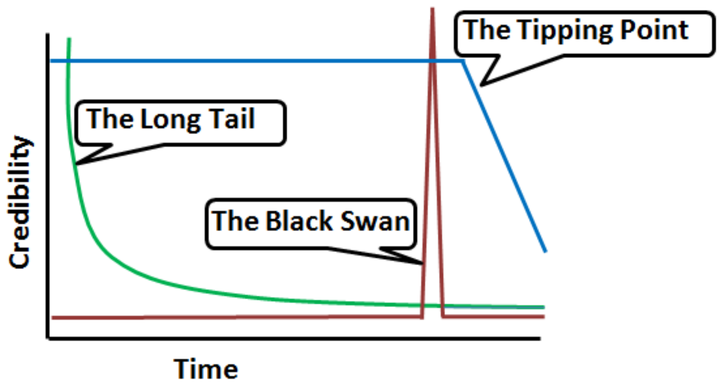
2. Connectivity Characteristics in Financial Networks

Currency markets are connected as a network of nodes and links, where the nodes represent countries, and the links represent the bilateral exchange rates (which determines the financial flow). Long-tailed network in the currency markets have two specific characteristics about their connectivity or links. First, long-tailed network exhibits the degree distribution that is thin in the middle and fat in the tails. In particular, it is characterized by a large number of small (weak) links and a small number of large (strong) links. Haldane (2009) pointed out that networks with long-tailed distributions have shown to be more robust to random disturbances, but more susceptible to targeted attacks. This is because most random shocks strike at the periphery of the network where their impact is distributed and can be absorbed easily. However, the impact of a targeted attack that strike at one of the massively connected nodes can spread to its entire network and the whole network can collapse (Haldane (2009), Dowe (2009)).

Figure 1 illustrates the long tail and the Black Swan event. The long-tail statistical property is found in a power law distribution curve, or Pareto distribution, where a larger share of population rests within the tail of a probability distribution. To the right of the curve is the long tail and to the left are the few that dominate.

[1] Long tail and scalability are exact opposite.

Figure 1 Long Tail and Black Swan



Notes: To the right is the long tail and to the left are the few that dominate.
Source: "Long Tail 101" URL: http://www.longtail.com/the_long_tail/2005/09/long_tail_101.html/

The second characteristic of a fat-tailed network is about small-world property. Small-world property displays the mechanics of six-degrees of separation, that is, the network has the potential for local disturbances to make long leaps. The subprime mortgage crisis in the U.S. displayed this characteristic, where infected banks that carry toxic assets infected another banks across the Atlantic in a short period of time. These banks are super nodes (JP Morgan, Goldman Sachs, Citigroup, Credit Suisse, Barclays Capital, Royal Bank of Scotland, Deutsche Bank, etc).

Some of these other properties of the global financial network and its consequences for stability are discussed in Haldane (2009). Haldane pointed out four key factors (i) connectivity, (ii) feedback, (iii) uncertainty, and (iv) innovation. Kubelec and Sá (2010, p23) also showed that

(1) The interconnectivity of the global financial network has increased significantly over the past two decades. This can be seen from the increase in the size of the nodes and the increase in the number and size of the links.
(2) The distribution of financial links exhibits a long tail. Measures of skewness and kurtosis show the asymmetry compared to the normal distribution. In particular, the global financial network is characterized by a large number of small-weak links and a small number of large-strong links. This suggests that a market with a high freedom of choice will create a certain degree of inequality by favoring the upper 20% of the items ("hits" or "head") against the other 80% ("non-hits" or "long tail"). This is known as the Pareto principle or 80–20 rule.
(3) The average path length of the global financial network has decreased over time. Average path length measures the average of the shortest distance between all pairs of nodes. In 2005 there are less than 1.4 degrees of separation on average between any two nodes.

(4) The network has become more clustered over time. The clustering coefficient measures the probability that, given that node *i* is linked to *j*, and *k*, nodes *j* and *k* are also linked to each other. The increase in this coefficient is another symptom of the increase in interconnectivity.

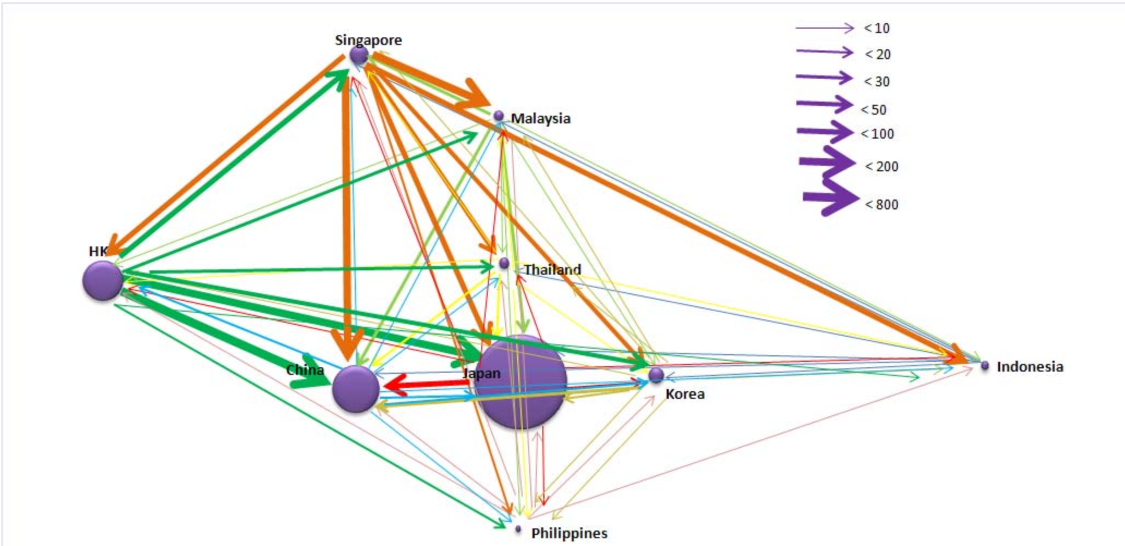
In contrast, links that have long-tailed distribution may not necessary have the property of scale-free networks whose robustness has been studied by Barabasi (1999, 2002), Albert and Barabási (2002) and Albert, *et al* (2004). Scale-free networks, demonstrated in World Wide Web, show that networks are very vulnerable to targeted attacks hitting a small number of large (strong) links due to their most interconnected nodes. However, a large number of small (weak) links are robust to random shocks, since a majority of these nodes have a few small links.

This study extends current features with a new stylized characteristic on currency markets. This concept is about every small node as having as many number of links as the big nodes, and a speculative attack on a small node may also spread high impact risks to big nodes. It may have a complete network with full rank. We show that targeted attacks can place severe stress on small nodes with catastrophic consequences, though without weakening the big nodes. The GFC saw that big banks were "too large to fail". The recent Greek Debt Crisis saw that for smaller countries that are members of larger unions, they too are "too small to fail". These rare events suggest that whether a node is too big or too small, all interconnected nodes are subject to a *Too-Interconnected-To-Fail* phenomenon (Markose, *et al*, 2010).

Today's many economic networks are an over-representation of a great many small nodes with weak (size) links and a few big nodes with strong (size) links due to globalization. The number of links between these nodes (small and large) in the network is equally large in numbers, and they do not exhibit much variability in the number of links. This pattern is seen in geographic trading bloc like the free-trade areas, such as AFTA (ASEAN Free Trade Area), North American Free Trade Agreement (NAFTA), European Economic Area (EEA), or even a common currency area like the Eurozone. In particular, small nodes with large (number) and weak (size) links are almost vulnerable to any kind of shocks.

Figure 2 plots the Asian financial network based on external financial assets and liabilities of Lane and Milesi-Ferretti (2007). The plot shows that Asia has an almost complete financial network with a connectivity of 0.9861 in 2008. Notice that there is an over-representation of a large number of small (weak) links and a small number of large (strong) links. Hong Kong and Singapore, both Asian international financial centers (IFC), are the only two major nodes that send/receive large amount of external financial assets (Table 1). The largest bilateral link is between Hong Kong and China (741.6%), which characterizes the feature of being a small number of large links.

Figure 2 Asian Financial Network: External Assets and Liabilities, 2008



Note: Links are given by the ratio of bilateral assets to GDP of the source country weighted by the trade weights. The size of the nodes is proportional to the country's financial openness, measured by the sum of its total external assets and liabilities.

Source: Lane and Milesi-Ferretti database.

Table 1 Size of Bilateral Links (%) for Asian Financial Network, 2008

	Indonesia	Malaysia	Philippines	Singapore	Thailand	Japan	Korea	China	Hong Kong
Indonesia		2.0	0.4	4.4	1.3	5.5	2.1	3.4	0.5
Malaysia	7.1		2.6	24.3	9.6	21.5	7.9	20.4	6.6
Philippines	1.5	3.0		5.8	3.0	9.8	3.7	6.6	4.7
Singapore	**82.3**	**122.0**	**18.8**		**37.8**	**65.8**	**46.7**	**100.1**	**59.6**
Thailand	4.1	6.9	2.0	6.1		18.9	3.7	12.8	4.2
Japan	9.0	7.9	3.7	6.9	10.0		17.7	53.3	8.3
Korea	2.8	2.3	1.2	3.6	1.5	13.0		24.5	3.2
China	2.3	4.0	2.1	3.9	3.1	19.8	13.8		15.1
Hong Kong	**9.4**	**24.8**	**19.3**	**66.8**	**28.0**	**112.9**	**46.9**	**741.6**	

Source: Lane and Milesi-Ferretti database.

The size of the bilateral link is weighted by trade weights and is computed as:

$$links_{ijt} = \frac{Assets_{ijt}}{GDP_{it}} = \widetilde{A}_{ijt}$$

The node i is linked to j at time t is defined as the ratio of gross bilateral assets (all asset classes – FDI, equity, debt, foreign exchange reserves) to GDP of the source country.

The size of the nodes is proportional to the country's financial openness, measured by the sum of its total external assets and liabilities (Table 2). Notice also that the size of the node is not a factor in determining the size of the links. Japan has the largest node (2.3), but the bilateral link between Singapore-China is even larger than Japan-China. All in the total number of nodes is 9, and the total number of links is 144, and average connectivity is 0.9861 (almost complete connectivity). This means that each country has almost a complete network with 16 links. On average, for a country to be qualified as an IFC, it needs its links as thick 100% or greater in order to allow large flows of funds.

Table 2 Size of Nodes (US$ million) for Asian Financial Network, 2008

	Total Assets	Total Liabilities	Total Assets and Liabilities	Size of Nodes
Indonesia	99924	260038	359962	0.0923
Malaysia	221632	195415	417046	0.1070
Philippines	63631	107028	170659	0.0438
Singapore	969874	749979	1719852	0.4412
Thailand	160274	176339	336612	0.0863
Japan	5705740	3236043	8941783	2.2936
Korea	482645	608488	1091132	0.2799
China	2897472	1477560	4375032	1.1222
Hong Kong	2260600	1637906	3898506	1.0000

Source: Lane and Milesi-Ferretti database.

3. The Dynamic Phasor Model

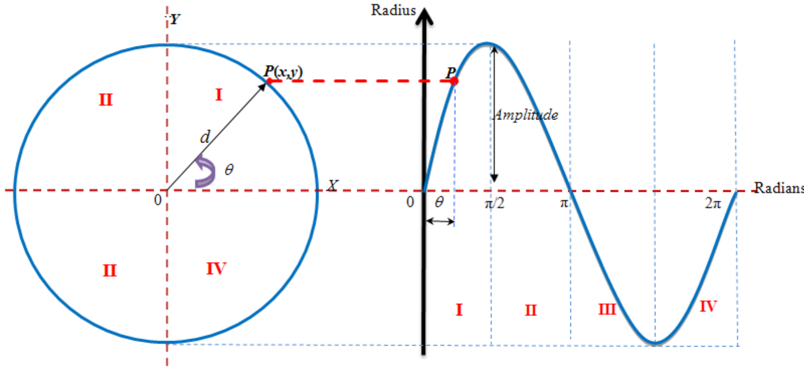
We introduce here a dynamic phasor model (Sheng, Kwek, Cho, 2009, 2010) based on engineering and physics principles to capture long-tailed networks. A network is an assemblage of elements called nodes, and nodes are connected to one another by a link. Mimicking the alternating electrical waves, we could plot economic variables in the alternating behavior against time (t) in terms of their waveforms. A sine wave is first used to demonstrate the feedback mechanism in the phasor model. Next, we overlap the sine and cosine waves to assess the policy state of a country.

Figure 3 shows a phasor ($0P$), that is the length of the straight line with an arrow, representing the magnitude of the quantity (x,y). The arrow indicates its direction. Consider now a phasor ($0P$), rotating in anticlockwise direction with uniform angular velocity (ω), from a starting position '0'. If the projections of this phasor on Y-axis are plotted against the angle turned through θ, a sine wave is formed. One complete cycle corresponds to 2π radians. As it requires time 't' to rotate through θ, so θ in radians can be expressed as,

$$\theta = \omega t \text{ radians,}$$

where ω is the angular velocity in radians/second. θ can also be expressed as $2\pi ft$, where $\omega = 2\pi f$ rad/sec. As this phasor has one cycle, its frequency is $f = 1$. The maximum value attained by an alternating quantity during positive or negative half cycle is its "Amplitude" (A).

Figure 3 Sine Wave and Phasor-Representation of an Alternating Quantity



Notes: The Phasor diagram consists of a circle and a cycle. The size of the circle is the height of the cycle (d). The radius (d) is called a Phasor ($0P$), and calculated by using the Pythagoras theorem: $d = \sqrt{x^2 + y^2}$. One phase consists of four quadrants (I, II, III, IV). The radius (d) on the circle is equivalent to an amplitude (A), the size of the sinusoidal wave. One complete cycle (one wavelength) of a sine wave is represented by one complete rotation of a phasor.

Mathematical Representation of the Sine Wave

Given a time series $y(\theta_t)$:

$$y(\theta_t) = Amplitude \times \sin\theta_t \qquad (1)$$

and

$$d(\theta) = \sqrt{x(\theta)^2 + y(\theta)^2} \qquad (2)$$

Then the phasor-velocity is the rate of change of phasor-position at time t:

$$\text{Phasor-Velocity} = v(\theta_t) = \frac{Phasor\text{ - }Displacement}{Time} = \frac{\Delta d(\theta_t)}{\Delta t} = \frac{d(\theta_t) - d(\theta_{t-1})}{\Delta t}. \qquad (3)$$

where $d(\theta_t)$ is the phasor-displacement for time-t. $\Delta d(\theta_t)$ is the change in the phasor-displacement, $\Delta d(\theta_t) = d(\theta_t) - d(\theta_{t-1})$, and t is time.

The mathematical form of the phasor-force, $C(\theta_t)$, is based on the angular velocity. Given that the "force-in-circular-motion" is ($F = \frac{m v_t^2}{r_t}$), where 'r' is the radius of the curvature is also 'd'.

In this phasor system, an economic mass (weight of a country) is assumed as $m = 1$. Therefore, the phasor-force is defined as a change in magnitude at a speed 'v' along a path with radius of curvature 'r' is:

$$\text{Phasor-Force} = C(\theta_t) = \varphi \frac{m\,v(\theta_t^2)}{r(\theta_t)} = \varphi \frac{m(d(\theta_{t+1}) - d(\theta_t))^2}{d(\theta_t)} \qquad (4)$$

where 'r' is the radius of the curvature is also 'd', and

φ is the directional coefficient.

If $(d(\theta_{t+1}) - d(\theta_t) > 0)$ then $\varphi == +1$, centrifugal force, or

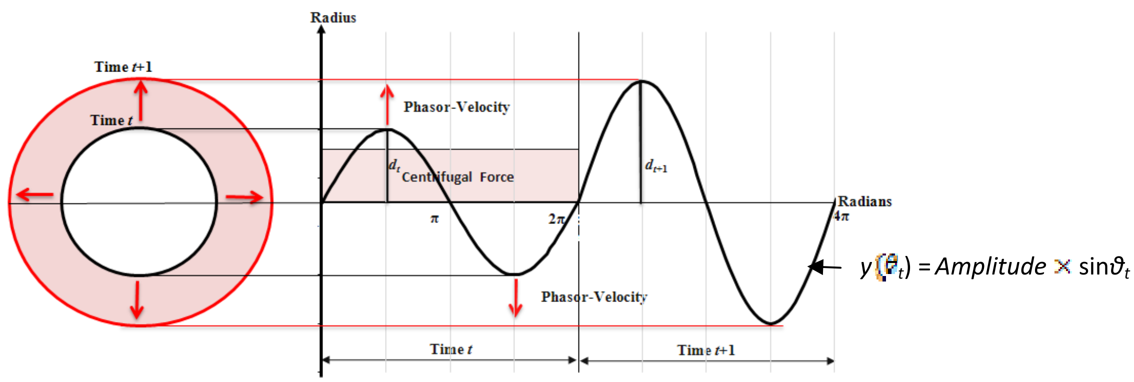
if $(d(\theta_{t+1}) - d(\theta_t) < 0)$ then $\varphi == -1$, centripetal force.

$C(\theta_t)$ is the "force" that would determine the size of the amplitudes for the sine waves.

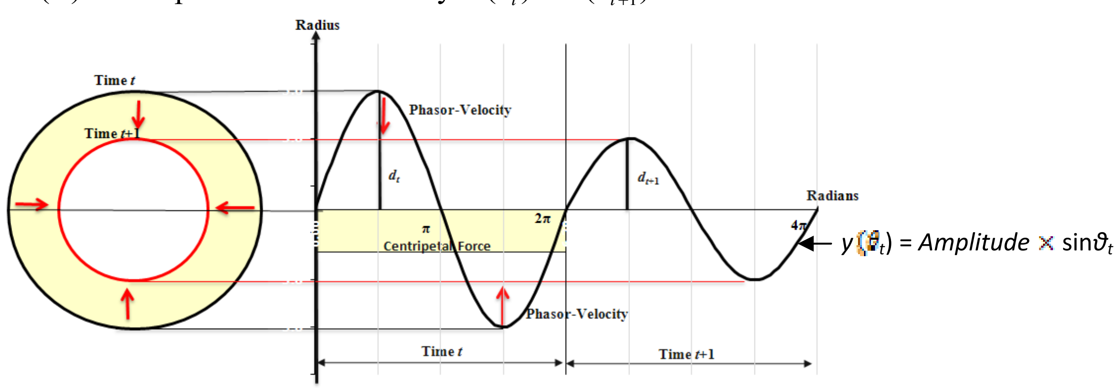
Figure 4 illustrates a representation for the feedback mechanism. It shows that with a positive feedback at time *t,* in the following period (t+1) the amplitude of the sine wave will be enlarged (Figure 4, Panel (A)). With a negative feedback at time *t,* in the following period (t+1) the amplitude of the sine wave will be reduced (Figure 4, Panel (B)). .

Figure 4 Feedback Mechanism Using Sine Waves

(A) Centrifugal Force caused by $d(\theta_t) < d(\theta_{t+1})$



(B) Centripetal Force caused by $d(\theta_t) > d(\theta_{t+1})$



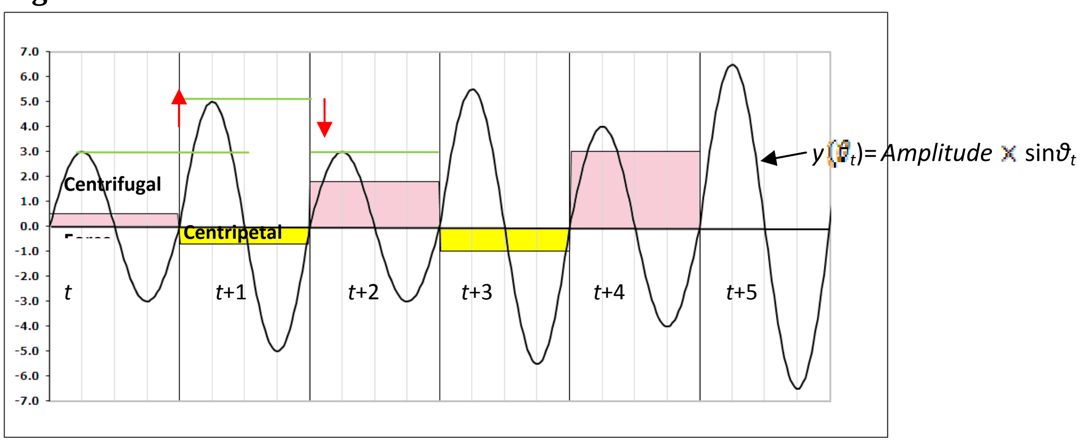
Notes: + Centrifugal Force
− Centripetal Force

Based on equation (3) and transforming it using $d(\theta_t) = \sqrt{x(\theta_t^2) + y(\theta_t^2)}$, and $y(\theta_t) = d(\theta_t)\sin\theta_t$ equation (2) can then also be denoted as:

$$v(\theta_t) = \frac{1}{\Delta t}\left[\frac{y(\theta_{t+1})}{\sin\theta_{t+1}} - \frac{y(\theta_t)}{\sin\theta_t}\right] = \frac{y(\theta_{t+1})\sin\theta_t - y(\theta_t)\sin\theta_{t+1}}{(\sin\theta_{t+1})(\sin\theta_t)}; \qquad (5)$$

Over time, the phasor-force has a time series behavior, $C(\theta_t)$, that follows a rectangular non-sinusoidal series (Figure 5). Predicting the time series behavior of $C(\theta_t)$ at time t is therefore helpful for forecasting the size of the sine wave or $y(\theta_t)$ for time t+1. Policy-makers are more interested and concerned with the positive feedback than with negative feedback in any economic system (Soros, 1987).

Figure 5 Time Series Sine Waves for Feedback Mechanism



Notes: + Centrifugal Force
− Centripetal Force

4. Capturing Speculative-Attack in Feedback Mechanism

To capture speculative attack using the feedback-phasors, nine major Asian currencies, *i.e.* the Indonesian Rupiah, Chinese Renminbi, Hong Kong dollar, Korean Won, Japanese Yen, Malaysian Ringgit, Philippines Peso, Singapore dollar, and Thai Baht are modeled in the currency markets. The study uses annual data, and the period of study is 1990-2008.

Let the coordinates $P(x,y)$ be replaced by $P(q, p)$ in the economic cartesian space. For the Y-axis, a price deviation variable (p) is used to depict price (exchange rates) distortions in the currency markets. This price deviation would reflect the price-adjustment policy of a country's exchange rate policy. For the *X*-axis, a quantity variable (*q*) is used to depict macroeconomic state of a country. This quantity-adjustment policy is measured by a country stock variable, which reflects the macro-stance through the ratio of current account balance and the level of Gross Domestic Product (CA/GDP). See Appendix (I).

Thus, the radius $d(\theta_t)$ is restated as:

$$d(\theta_t) = \sqrt{q(\theta_t^2) + p(\theta_t^2)}$$

$$= \sqrt{Quantity\ Adjustment\ Policy + \mathrm{Pr}ice\ Adjustment\ Policy}$$

$$= \sqrt{\left(\frac{CA}{GDP}\right)_t^2 + (DevFEER)_t^2} \qquad (6)$$

The price-adjustment policy, that is the deviation from the fundamental equilibrium exchange rate (DevFEER), Cline and Williamson (2008, 2010), is the object of interest in this study. This variable is also a measure of currency misalignment from the underlying long-run trend or long-run equilibrium. It also reflects the amount of currency distortions due to cross-border transaction costs, diverse foreign exchange administration rules, and other pricing controls which can distort the operation costs of managing cross-border flows of currencies.

Summarizing these four overlapping quadrants gives four regions of imbalances:
Quadrant I : Surplus and Undervaluation (S,U),
Quadrant II: Deficit and Undervaluation (D,U),
Quadrant III: Deficit and Overvaluation (D,O), and
Quadrant IV: Surplus and Overvaluation (S,O).

In an economic sense, Quadrants II, III and IV are not sustainable in the long-run. Quadrant I is the most preferable quadrant by policy-makers, because a country with current account surplus and undervaluation of its exchange rates can act as a buffer to reduce the impact of a targeted attack on its domestic economy.

Table 3 gives the empirical estimates for $d(\theta_t)$, the phasor-displacement in equation (2) for the nine Asian currencies, and these *d*s are used to compute the estimates of the phasor-velocity, $v(\theta_t)$, in equation (3). These computed $d(\theta_t)$ for the circles are also amplitudes for the sine waves, which give the waveform representations for the $y(\theta_t)$ variable, *i.e.* deviation of the fundamental equilibrium exchange rate or currency misalignment due to misallocation of domestic resources.

Table 3 Empirical Estimates for Phasor-Displacement $d(\theta_t)$, and Phasor-Velocity $v(\theta_t)$, for Asia (1992 – 2008)

	Indonesia		Malaysia		Philippines		Singapore		Thailand		Japan		Korea		China		Hong Kong	
	d_t	v_t	d_t	v_t	d_t	v_t	d_t	v_t	d_t	v_t	d_t	v_t	d_t	v_t	d_t	v_t	d_t	v_t
1992	2.23	0.50	3.80	-0.87	2.14	-4.05	11.90	4.64	5.74	0.56	3.13	-0.26	1.64	0.90	1.62	-1.21	3.18	-2.06
1993	1.74	-0.10	4.67	-1.52	6.19	1.19	7.26	-9.00	5.19	-0.47	3.39	0.29	0.74	-0.59	2.84	1.11	5.23	4.04
1994	1.83	-1.99	6.19	-3.69	5.00	1.93	16.26	-0.96	5.66	-2.54	3.10	-0.71	1.33	-0.98	1.73	-0.06	1.19	-5.24
1995	3.82	-0.47	9.88	5.26	3.06	-2.30	17.22	2.14	8.20	-0.03	3.81	-1.91	2.31	-2.93	1.79	-0.15	6.43	3.47
1996	4.29	1.53	4.63	-1.44	5.36	-0.28	15.08	-0.67	8.24	6.18	5.72	2.45	5.24	3.17	1.93	-1.84	2.96	-1.44
1997	2.75	-6.52	6.06	-7.28	5.64	2.53	15.74	-6.98	2.06	-10.86	3.27	-0.17	2.07	-10.97	3.77	0.76	4.40	2.88
1998	9.27	1.77	13.34	-2.72	3.10	-0.73	22.73	4.93	12.92	2.67	3.44	0.81	13.04	6.78	3.02	1.01	1.52	-4.77
1999	7.50	-0.03	16.06	6.60	3.83	0.77	17.80	6.00	10.25	2.57	2.62	-0.03	6.26	3.70	2.01	0.15	6.29	2.14
2000	7.53	0.16	9.45	1.14	3.07	0.32	11.80	-2.47	7.68	3.20	2.66	-0.42	2.56	0.84	1.86	0.26	4.15	-1.73
2001	7.37	-0.45	8.31	0.72	2.74	2.14	14.26	0.20	4.48	0.72	3.08	0.21	1.73	0.49	1.60	-0.86	5.87	-1.76
2002	7.82	-1.49	7.59	-5.45	0.60	-2.20	14.06	-10.90	3.76	0.19	2.87	-1.00	1.24	-1.69	2.46	-0.33	7.64	-3.27
2003	9.31	-1.95	13.04	0.65	2.80	-0.68	24.96	2.10	3.57	1.53	3.87	0.11	2.93	-1.01	2.79	-1.02	10.91	-25.06
2004	11.26	0.55	12.39	-2.11	3.48	0.26	22.87	-14.46	2.05	-2.73	3.76	0.07	3.94	2.05	3.81	-3.33	35.97	22.97
2005	10.70	5.80	14.50	-1.83	3.23	-2.44	37.33	6.90	4.78	3.55	3.69	-1.53	1.89	0.05	7.14	-2.51	13.00	0.81
2006	4.90	-4.78	16.33	0.49	5.67	0.19	30.44	11.02	1.23	-0.67	5.21	-0.52	1.84	-0.08	9.65	-0.42	12.19	3.17
2007	9.68	-9.72	15.84	-2.12	5.48	-1.60	19.41	2.49	1.90	0.09	5.74	-0.37	1.92	-2.28	10.07	-0.02	9.02	-5.16
2008	19.40	19.40	17.96	17.96	7.08	7.08	16.92	16.92	1.80	1.80	6.11	6.11	4.20	4.20	10.09	10.09	14.18	14.18

The computed values of the phasor-velocity, $v(\theta_t)$, are then used to compute the values for the phasor-force, in equation (4) for 1992-2008 (Table 4).

Table 4 Parameter Estimates for the Phasor-Force $C(\theta_t)$

	Indonesia	Malaysia	Philippines	Singapore	Thailand	Japan	Korea	China	HK
1992	-0.112	0.199	7.682	-1.812	-0.054	0.022	-0.495	0.904	1.331
1993	0.005	0.496	-0.229	11.166	0.043	-0.025	0.466	-0.432	-3.115
1994	2.160	2.204	-0.748	0.056	1.142	0.163	0.725	0.002	22.949
1995	0.057	-2.795	1.721	-0.267	0.000	0.961	3.730	0.012	-1.871
1996	-0.548	0.446	0.014	0.029	-4.638	-1.050	-1.917	1.757	0.700
1997	15.426	8.733	-1.139	3.099	57.333	0.009	58.057	-0.153	-1.884
1998	-0.339	0.553	0.171	-1.069	-0.551	-0.193	-3.526	-0.336	14.942
1999	0.000	-2.714	-0.153	-2.024	-0.643	0.000	-2.182	-0.011	-0.729
2000	-0.003	-0.137	-0.034	0.516	-1.335	0.067	-0.272	-0.036	0.718
2001	0.028	-0.063	-1.668	-0.003	-0.115	-0.014	-0.137	0.462	0.530
2002	0.284	3.913	8.001	8.452	-0.009	0.346	2.300	0.044	1.401
2003	0.406	-0.032	0.166	-0.176	-0.653	-0.003	0.347	0.374	57.554
2004	-0.027	0.358	-0.019	9.148	3.637	-0.001	-1.063	2.901	-14.668
2005	-3.145	0.231	1.849	-1.274	-2.638	0.632	-0.002	0.881	-0.051
2006	4.658	-0.015	-0.006	-3.992	0.365	0.052	0.003	0.018	-0.825
2007	9.758	0.283	0.468	-0.320	-0.005	0.024	2.711	0.000	2.953
2008	-0.820	-1.250	-2.080	-0.083	1.440	0.243	0.730	-0.283	3.214
2009*	**-2.708**	**1.202**	**1.592**	**-2.011**	**-7.546**	**0.072**	**-6.791**	**-0.049**	**5.005**
2010*	**2.307**	**-0.794**	**-0.629**	**2.510**	**2.701**	**-0.282**	**2.997**	**0.343**	**-9.253**

Notes: + Sign is centrifugal force, and – Sign is centripetal force

Interestingly, the estimated phasor-force results for 2009 and 2010 in Table 4, suggest that some Asia countries (excluding Indonesia, Malaysia, the Philippines, Singapore, and China) were not spared from the Global Financial Crisis of 2008, the second 'rare event' with long-tailed black swan risk in Asia. This time round, only two countries experienced such extreme values of positive feedback, namely Hong Kong and Japan (in 2009). Hong Kong received the largest positive feedback of 5.0048, and interestingly, Japan received the smallest positive feedback value of 0.0719.

These extreme positive values in Hong Kong were fallouts triggered by sale of mini junk bonds sold by Lehman Brothers. On September 15, 2008, Lehman Brothers filed for Chapter 11 bankruptcy protection (marking the largest bankruptcy in U.S. history) following the massive exodus of most of its clients. It was not surprising that Hong Kong was most exposed. Hong Kong housed eight of the Lehman Brothers' based units: Lehman Brothers Asia Holdings Limited, Lehman Brothers Securities Asia Limited, Lehman Brothers Futures Asia Limited, Lehman Brothers Asia Limited, Lehman Brothers Commercial Corporation Limited, Lehman Brothers Asia Capital Company, LBQ Hong Kong Funding Limited and Lehman Brothers Nominees (HK) Limited. In contrast, the Japanese Yen exposure to the GFC was hedged by its exchange rate flexibility. This gives room for its exchange rate to adjust or "wiggle" its way out of the tail risk to restore financial stability. However, the depreciating US dollar has instead fuelled the Yen carry trade.

Figure 6 plots the feedback mechanism for the estimated sine waves $y(\theta_t)$ and the phasor-force $\hat{C}(\theta_t)$. This Figure clearly shows the size of the 'rare event' (extremes positive feedback values) in 1997/1998, *i.e.* the Asian Financial Crisis, had badly damaged the network of four countries, namely, Korea, Thailand, Indonesia and Malaysia. First, notice how the size of the sine waves were greatly enlarged in 1998 after contracting a positive feedback in 1997. This enlarged sine waves due to positive feedback in the previous period. This positive feedback is consistently demonstrated in these four crisis economies. Second, also notice that the following period (1999), these extreme positive feedback values have dissipated, and that it occured only once like a Black Swan, and the impact of the highly improbable. The consecutive size of the sine wave is reduced substantially.

The aftermath of the AFC saw Thailand switched from a fixed exchange rate regime to a managed floating exchange rate regime with inflation targeting framework. For the case of Malaysia, she switched from a managed floating exchange rate regime to a pegged to the US dollar exchange rate regime. Hong Kong, which adopts a Currency Board for its exchange rate arrangement, is the only country in Asia that had experienced large positive feedback. Hong Kong is able to withstand such large positive feedback because it has accumulated large foreign reserves, US$92.8 billion, to defend itself from speculative attacks on its domestic currency. Hong Kong's foreign reserves had increased to US$182.47 billion in 2008, a 98% increase.

Figure 6 Capturing Speculative Attack Through Feedback Mechanism

Notes: Extreme Positive Feedback is defined as Speculative-Targeted Attack.

- Centrifugal Force due to Positive Feedback
- Centripetal Force due to Negative Feedback

5. Assessing Policy-Space in Network-Phasors

We can further model the market movements caused by the confluence of different market forces, by transforming the market movements (x,y) into sinusoidal waves (cosθ, sinθ). In particular, when the two forces collide (cosθ = sinθ), they create directions that are not always predictable, though the amplitude of the sine waves and the cosine waves are predictable.

Here, we apply the sinusoidal waves to be used to assess the policy state of a country. Overlapping the sine (sineθ) and cosine (cosθ) waves will map the *policy-space* of a country. This policy-space (yellow area) can be used to interpret the economic state of macroeconomic policies, *i.e.* in normal state (stable state) versus abnormal state (crisis state) (Figure 7). In normal state, the area between the sine and cosine waves would be large. In a crisis state, the *policy-space* would narrow.

Normal State

In normal condition, the location of the red dot and the blue dot is far apart. Thus, the value of cosθ ≠ sinθ (red dot is apart from the blue dot). The further apart value of the cosθ from sinθ, the more successful are economic policies in influencing the economy (as they are "coordinated").

Abnormal State

In abnormal condition, the location of the red dot and the blue dot will be overlapped. The value of cosθ = sinθ. At this point, the sine wave also intersects with the cosine wave.

Figure 7 Policy-State Representation through Sinusoidal Waves

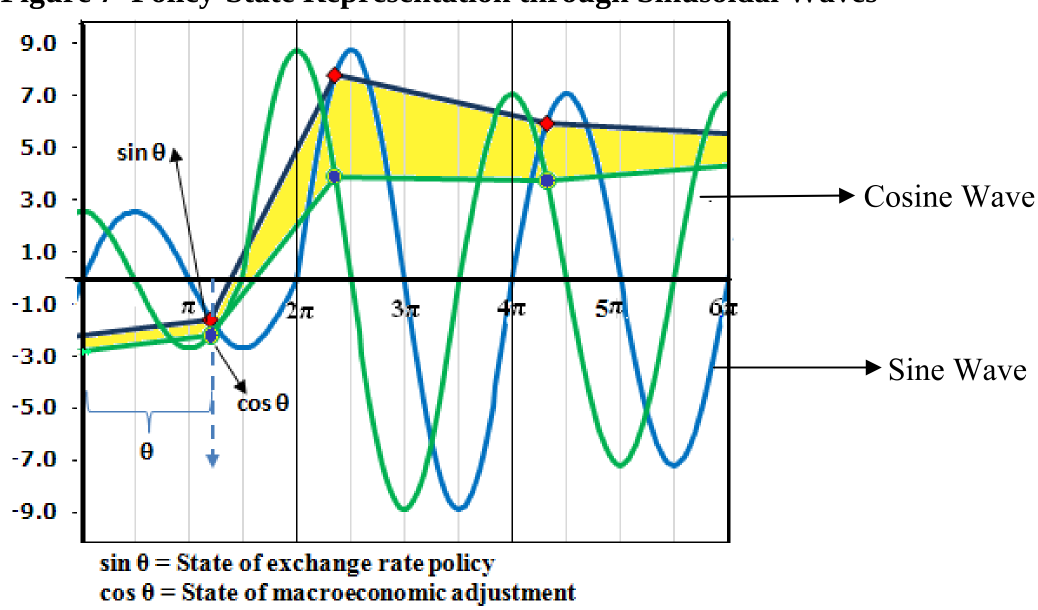


Figure 8 plots the policy-state for the network-phasors in the nine currencies. It is worth noting that the speculative targeted attack and the collapse of the Thai baht in 1997, saw the "clash" of the sine and cosine waves for Malaysia, Indonesia, and Korea. Interestingly, this network effect demonstrates that nodes with stronger links are less susceptible to the long-tailed Black Swan risks, like the Japanese Yen and the Singaporean dollar.

Notice also that Singapore and Hong Kong in the 2000s, have financial networks which are characterized by thick policy-space – which also reflects the country status' as an IFC. This is because Hong Kong and Singapore, being IFCs, need not "fly in concert" with the common network. Malaysia's sizeable policy-space could be explained by its strategy to establish her as the international Islamic financial centre.

6. Conclusion

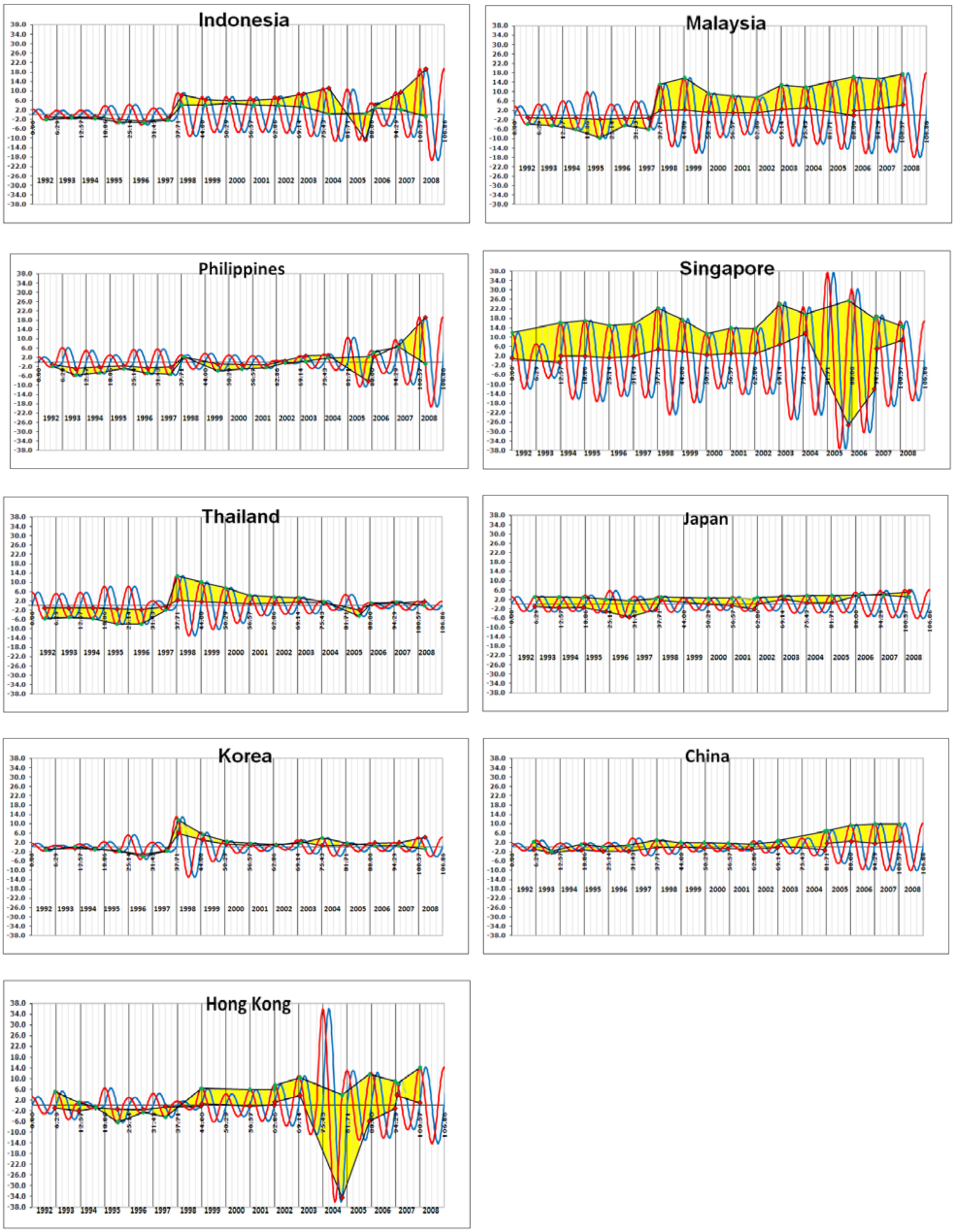
Exchange rates networks can be characterized by fat-tailed networks characteristics. A speculative-targeted attack at one of the small nodes with weak links in the system could also cause wide-spread damage. In this sense, a fat-tailed network with 'small world' property, tells us that today's financial phenomena are too-interconnected-to-fail.

The results of the study do show that we are able to capture these rare events. While not all directional changes are predictable due to lack of contextual information that we may not be able to capture, there are certain patterns of behaviour that conform with tools common in engineering and physics.

First, the findings strongly show that a targeted attack, like the Asian Financial Crisis, at any one of weak nodes, it can cause smaller and bigger nodes in the network to collapse. Second, the findings also suggest that exchange rate flexibility is a very important feature for a country to absorb any Black Swan risk. Any speculative targeted attack would also change the nature of the exchange rate regime. For instance, Thailand switched from fixed to floating, and Malaysia switched from floating to fixed during the Asian Financial Crisis (Ito, 2007, Sheng, 2009). Third, the policy-space of the network-phasor can be used to predict any impending crises. Large policy-space is preferred as it can be used to buffer any speculative attack. When the two forces collide ($\cos\theta = \sin\theta$), the size of the amplitude of the following sine waves and the cosine waves are always enlarged.

Interestingly, applying the *network theory* to exchange rate systems do conform to tools common in engineering and physics measured through their alternating feedback mechanism. The *network theory* could capture these network behaviors of these nine Asian currency markets, because the network effect for Asia has gone through regionalism, a process that was created through shared market risks, and coordinated macroeconomic policies.

Figure 8 Policy-Space in Network Phasors



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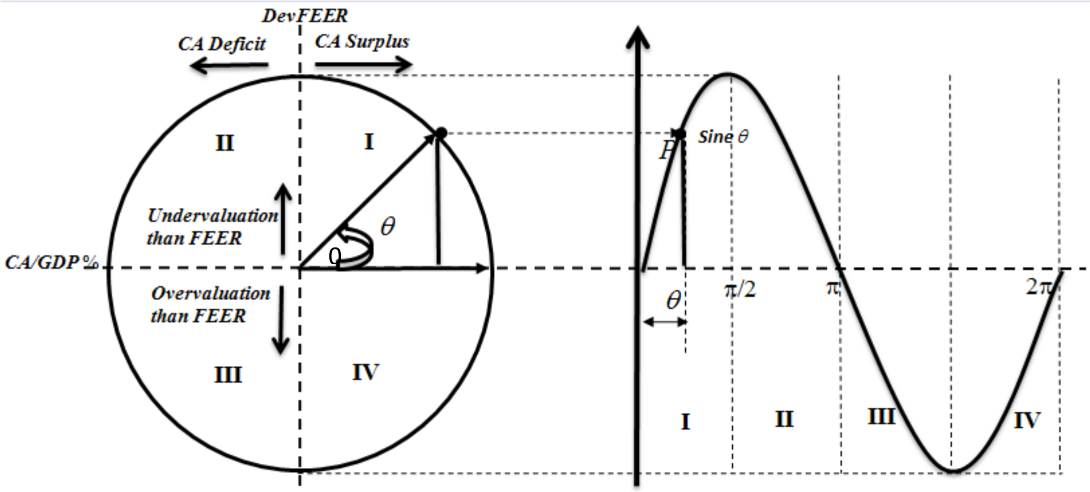
APPENDIX (I)

I. Phasor Representation and Waveforms in Economic System



The origin "0" implies no market distortions either in the currency market or the current account balance. Markets are balanced, and are in equilibrium (demand equals supply).

The *Y*-axis represents country's Price-Adjustment Policy.
For the *Y*-axis, the deviation from the fundamental equilibrium exchange rate, denoted as *DevFEER*, represents price distortions for the currency market. It is an index that reflects the deviation of country's bilateral exchange rates from the fundamental equilibrium exchange rates (FEERs). FEER is a concept based on the works of John Williamson, the father of macroeconomic exchange rates misalignment (see See URL:
http://www.iie.com/staff/author_bio.cfm?author_id=15).

If *DevFEER* = 0, it means market distortions does not exist.
If *DevFEER* > 0, it implies the spot exchange rate against the US dollar is undervalued (U).
And if *DevFEER* < 0, it implies the spot exchange rate against the US dollar is overvalued (O). *DevFEER* is computed as the deviation of the bilateral exchange rate index (1992 = 100) from the fundamental equilibrium exchange rates.

The *X*-axis represents country's Quantity-Adjustment Policy.
For the *X*-axis, when CA = GDP, it implies a quantity of balanced macro stance. However, this situation is impossible to achieve in economic realities.
If CA > GDP, it implies current account surplus (S), and if CA < GDP, it implies current account deficit (D).