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ASIAN CRISES: THEORY, EVIDENCE, WARNING-SIGNALS

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ASIAN CRISES: THEORY, EVIDENCE, WARNING-SIGNALS

Abstract

In July 1997, the economies of East Asia became embroiled in one of the worst financial crises of the postwar period. Yet, prior to the crisis, these economies were seen as models of economic growth experiencing sustained growth rates that exceeded those earlier thought unattainable. Why did the market not anticipate the crises? To this end, we review the Asian financial crisis from two related perspectives - whether the crisis was precipitated by a failure of the real exchange rate to be aligned with its fundamental determinants and/or whether the crisis was precipitated by a divergence of the foreign debt from its optimal path. The first perspective is based on a coherent theory of the equilibrium real exchange rate - the NATREX model - that shows how "misalignments" lead to currency crises. The second perspective is based on a model of optimal foreign debt ratio - derived from stochastic optimal control - which shows why "divergences" lead to debt crises. The important point here is that these models suggest important variables which may serve as warning signals to predict crises.

JEL classification: F3, F31, F32, F34, F4.

Keywords: asian crises, optimal debt, equilibrium exchange rates, NATREX, stochastic optimal control, warning signals of crises, exchange rate misalignment.

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1. Aims of the Study

In July 1997, the economies of East Asia became embroiled in one of the worst financial crises of the postwar period. Yet, prior to the crisis, these economies were seen as models of economic growth experiencing sustained growth rates that exceeded those earlier thought unattainable. Table 1 describes the situation for ASEAN4 and Korea before and after 1997. The high growth from 1986-96 was suddenly followed by a collapse of the real economy, with negative growth in 1998. In 1997, the exchange rates depreciated by double digits and, for some countries, the depreciation continued into 1998.

Table 1: The Asian Crisis 1997-98

Country	GDP: Annual Growth Rate %		Exchange-rate Depreciations %	
	1986-96	1998:1-1998:6	1997	1998:1-1998:6
Indonesia	7.4	-12.0	-52.0	-50.0
Korea	8.6	-5.0	-43.0	6.0
Malaysia	7.8	-5.0	-33.0	-1.0
Philippines	3.7	-12.5[(a)]	-29.0	-5.0
Thailand	9.1	-8.0	-44.0	16.0

Source: IMF, Oct. 1998, tables 3.11, 3.12. (a) 1997:4-1998:2

What went wrong? What caused the financial crisis? With hindsight, there is now a consensus as to what went wrong with the Asian countries. Dean (2003)[1] briefly describes the consensus as follows. The Asian growth was generated by high investment and saving. The difference was financed by capital inflows, made possible when the economies were liberalized in the early 1990s. Since these economies generally had

[1] Dean (2001) contains the basic references on this subject, and the reader is referred to his article for the extensive bibliography. Flouzat (1999) and recent International Monetary Fund WEO reports describe the consensus view country by country.

fixed exchange rates, the capital inflows led to increases in the money supply. There was inflation of asset prices, speculative bubbles, but not inflation of prices of goods and services. The investment was poorly intermediated and misallocated.

The capital inflows produced a high ratio of external debt and debt service obligations relative to export earnings. With the bursting of the speculative bubble in asset prices, the former capital inflows turned to outflows. The countries faced a dilemma. If interest rates were raised to stem the outflow, the debt service burden to domestic borrowers would be raised. If the interest rates were not raised, devaluation would have to occur; and the debt service burden on the foreign currency denominated debt would rise. The net result was a financial collapse and exchange rate depreciation.

But why did the market not anticipate the crises?[2] Could it be that the market and credit rating agencies failed to anticipate the crisis because there were no useful warning signals? More importantly could it be that the range of qualitative and quantitative indicators normally monitored (for example, per capita income, growth rates, inflation rates, ratios of foreign debt to exports, history of defaults, level of economic development, government budget deficits, ratio of current account deficits to GDP) were not helpful because these measures were assessed in an ad hoc manner?

We contend that it would be more useful to derive warning signals based on concepts derived from a coherent theoretical framework which can predict the crisis. Hence our aim is to present a coherent theory which may be used generate operational warning signals. To this end, we review the Asian financial crisis from two related perspectives - whether the crisis was precipitated by a failure of the real exchange rate to be aligned with its fundamental determinants and/or whether the crisis was precipitated by a divergence of the foreign debt from its optimal path. The first perspective is based on a coherent theory of the equilibrium real exchange rate which shows how "misalignments" lead to currency crises. The second perspective is based on a model of optimal foreign debt ratio which showed why "divergences" lead to debt crises. The important point here is that these models suggest important variables which may serve as warning signals to predict crises.

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[2] Available measures of expectations by market participants display a poor record in anticipating crises. The secondary market yield spreads on US dollar denominated Eurobonds did not vary much before the Asian crisis, see IMF, WEO Dec. 1997, figure 14; International Capital Markets, September 1999: 107-12. See also Berg and Pattillo.

The paper is organized as follows. In section 2 of the paper we discuss some traditional warning signals. Section 3 provides an overview of the Natural Real Exchange Rate (NATREX) approach to the determination of the equilibrium real exchange rate and the measure of misalignment that may serve as a warning signal for currency crises. This section also describes the stochastic optimal control/dynamic programming (SOC/DP) approach to derive the optimal foreign debt ratio and shows how the deviation of the actual debt from this benchmark measure of performance may serve as a sufficient condition for a debt crisis. In section 4 we explore the explanatory value of our theoretically-based warning signals all *utilizing only available information* to explain and predict the Asian crises. Concluding remarks are contained in the final section 5.

2. Traditional Warning Signals

This paper is concerned with two types of crises. The first is a *currency crisis,* which results from an "overvalued" exchange rate, and the second is a *debt crisis,* which occurs when the country cannot service its foreign debt. In both cases, the likely outcome is a dramatic currency devaluation or depreciation.

A common view associated with currency crises is that they result from "unstable macroeconomic policies". Consequently the early warning measures are the state of key macroeconomic variables and the response to a currency crisis is to implement restrictive monetary and fiscal policies.[3] Section 2.1 below explains why the crises in Asia could not be explained by "unstable macroeconomic policies". Debt crises are associated with "unsustainable" external debt and section 2.2 reviews a few traditional measures of "unsustainability".

Warning Signals have two components. (a) What variables are considered? (b) What periods are compared? In this section, we focus primarily upon International Monetary Fund WEO reports that organized the data in forms (a) and (b) above: variables and comparison periods. For example, table 2 is based upon the IMF's presentation. We show the limitations of the standard approaches.

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[3] Some economists have argued that the way to avoid currency crises is to adopt a currency board or to replace the domestic currency with a foreign currency.

2.1. Was there Macroeconomic Instability?

It is now a well-documented that the Asian crises were not preceded by increases in "macroeconomic instability". Table 2 compares some macroeconomic indicators for the pre-crisis period 1986-96 with the earlier tranquil period 1975-85. Inflation declined, and there were no significant increases in fiscal deficits or current account deficits. By the usual standards of macroeconomic performance the Asian economies were doing very well. In fact, prior to the crises, according to the International Monetary Fund (October 1998, ch.III, pp.82ff), the successful economic performance of these East Asian countries can be attributable to their emphasis on stability oriented macroeconomic policies such as maintaining low rates of inflation, avoiding overvalued exchange rates, and sustaining high rates of physical and human capital accumulation and export oriented production. This evidence leads one to reject an assertion that the crises were produced by monetary and fiscal mismanagement.

Table 2 Macroeconomic Variables 1975-85 and 1986-96

Country	Inflation % p.a.		Fiscal balance/GDP %		Current account/GDP %	
	1975-85	1986-96	1975-85	1986-96	1975-85	1986-96
Hong Kong	8.2	8.0	1.1	2.1	3.0	5.6
Indonesia	13.4	8.2	0.3	-0.5	-2.0	-2.8
Korea	13.5	5.7	-2.2	-0.1	-3.7	0.9
Malaysia	4.8	2.6	-5.3	-2.4	-3.2	-2.6
Philippines	15.6	8.9	-2.0	-2.3	-5.1	-2.6
Singapore	3.4	1.9	1.9	9.1	-7.2	9.5
Taiwan	6.3	3	0.3	-0.5	4.3	7.8
Thailand	7.2	4.5	-3.7	2.1	-5.5	-4.9

Source: International Monetary Fund, October 1998, table 3.11

However, the currency did collapse and that leads one to question the usefulness of the above macroeconomic variables as warning signals of vulnerability. In section 3, we suggest that it may be more useful to look at the behavior of the fundamental determinants of the real exchange rate to predict the probability of a currency crisis. Our warning signals are based on a theoretically justifiable concept and measure of exchange rate misalignment.

2.2. Was the Foreign Debt Sustainable?

Since the crises could not be attributed to "macroeconomic instability", the focus turned to the role of the external debt[4] and to the weaknesses in the financial structure as explanations of the crises. For the Asian economies, the banking system was the means by which foreign lending was intermediated through the corporate sector. Equity markets played a limited role, and fixed income money and bond markets were less developed and liquid. Table 3 describes the net private capital flows to Asia.

Table 3 Net private capital flows to Asia

$billion	1990	1991	1992	1993	1994	1995	1996	1997	1998
Total investment	19.6	34.1	17.9	57.3	66.4	95.1	100.5	3.2	-55.1
Net foreign direct	9.3	14.4	14.8	33.0	45.3	49.8	55.1	62.6	50.0
Net portfolio; Bond and equity	-2.7	1.4	7.8	21.0	9.4	10.9	12.6	0.9	-15.4
Bank loans,Investments	13.0	18.4	-4.7	3.3	11.7	34.4	32.8	-60.3	-89.7

Source: IMF, International Capital Markets, September 1999, table 3.1

Table 3 shows the volatility in total capital flows. Net foreign direct investment was the main component of the capital flows, 55% in 1996, and was relatively steady. The highly volatile element was the category of bank loans, which was about 33% in 1996. It switched from an inflow of $32.8 billion in 1996 to an outflow of $89.7 billion in 1998. What caused the turnaround? Clearly the outflow reflected a reaction to a

[4] Both domestic and foreign investors held domestic debt. Since part of the domestic debt was sometimes denominated in foreign currency or linked to the exchange rate, the distinction between domestic and foreign debt becomes blurred (see, Berg and Pattillo).

perceived weakness in the nature of the foreign debt. Can we identify some features which may be used as indicators of financial stress?

Consider first, an assessment of financial vulnerability from a perspective on the composition of debt. The Fund considers countries with high levels of short term debt, variable interest rate debt and foreign currency denominated debt as being particularly vulnerable to internal and external shocks and thus as susceptible to financial crises.[5] Was the Fund's view correct? Arteta (2003) investigated two questions. First, does high dollarization of deposits and credits increase the likelihood of banking crises and currency crashes and second does the dollarization make these crises and crashes more costly? He used a comprehensive dataset on deposit and credit dollarization for a large number of developing and transition economies and based on extensive econometric estimation finds little evidence of any particular link between high bank dollarization and the likelihood of banking crises or currency crashes.

Next consider a macroeconomic aggregate approach based on a widely used measure of "solvency" or "sustainability" to assess the excessiveness of foreign debt.[6] The measure of *solvency* is the net resource transfer (that is the trade surplus) that an indebted country must have to keep the ratio of external liabilities to GDP a constant. The argument is that the greater is the long term resource transfer, the greater is the probability of a debt crisis. More specifically, the "sustainability" argument asks what will be the value of the steady state debt/GDP (in this paper denoted as h^*) if current policy as measured by the current account deficit/GDP were to continue at the current growth rate? *The standard argument is that the greater is the equilibrium value of the debt h^* based upon current policy, the greater is the probability of a crisis.*

To empirically apply this concept, the standard approach is to calculate h^* as the ratio of current account deficit/GDP divided by the growth rate of GDP. This is because in the steady state, when the ratio of debt/GDP has stabilized, the ratio of the current account deficit to the debt is equal to the growth rate. Hence h^* is as defined below. Table 4 presents the average value of h^* over two sample periods, the pre-crisis period

[5] See IMF, WEO, May 1998: p.85.
[6] See IMF, WEO, May 1998: 86-87; October 2003, ch. III

1986-96 and the corresponding 1975-85 tranquil period, for the Asian countries that experienced crises.

Table 4: Measure of "Sustainability"

Country	h^* = (Current Account deficit/GDP)/growth rate	
	1975-85	1986-96
Hong Kong	-0.37	-0.89
Indonesia	0.35	0.38
Korea	0.49	-0.10
Malaysia	0.51	0.33
Philippines	1.76	0.68
Singapore	1.0	-1.13
Taiwan	-0.52	-1.01
Thailand	0.83	0.54

Positive values of h^* are debtor positions.

As shown in Table 4, for Indonesia, there was no significant change in the "sustainable debt" measure; for Korea, the pre-crisis policies would have led to a creditor rather than to a debtor situation. Similarly, Malaysia, Philippines and Thailand would have become less of a debtor. In other words, the current account deficit/GDP ratios in the pre-crisis period, were the same or less than what they were a decade earlier for the ASEAN4 and Korea. In other words, these measures of sustainability would have failed to signal problems ahead for the Asian countries affected by the crisis.

The failure of the above "sustainability" approach arises because, as explained in Stein and Paladino (2001), the growth rate is simply related to the current account without taking into account the purpose of the foreign borrowings. If the current account deficit finances productive investment, then present current account deficits will generate future growth. The latter can make the economy more competitive and increase future trade balances. Moreover, another point to note here is that the actual debt to GDP ratio by itself is also *not* a relevant variable in predicting a debt crisis. For example, the ratio

of debt service payments/exports for the Asian countries did not rise in the years before the crisis, as seen in table 5 below[7].

Table 5: Debt Service/Export Ratios (%)

	1989	1990	1991	1992	1993	1994	1995	1996
Asian countries	20.9	17.7	17.3	18.1	17.8	16.0	15.7	16.1
Developing countries	24.5	21.3	22.7	23.8	23.8	23.1	22.0	23.1

2.3 Summary of Market Anticipations.

The International Monetary Fund, International Capital Markets (September 1999, chapter V and annex V) contains a comprehensive analysis of market anticipations prior to the Asian crises. We draw upon and paraphrase the analysis contained there to evaluate the "early warning signals" used.

Global securities markets became important sources of funding for many emerging market countries in the period of the 1990s. The portfolio preferences of the major institutional investors became key determinants and conditions of capital flows. Credit rating agencies had great influence upon the effective cost of capital charged by international lenders to the borrowers in the emerging market countries. In many cases, intuitional investors are constrained to hold securities that have been classified by rating agencies as investment grade. Therefore, the cost of capital is effectively reflected in the ratings of the agencies and/or the bond spread. These two variables should reflect the market anticipation of crises, whereby the debtor may experience difficulties in servicing the debt.

Although the rating agencies stress that they do not use a specific formula to derive their ratings, empirical researchers explained the ratings as a weighted average of key indicators. Warning signals used by the international market are reflected by low credit ratings. The statistically significant variables to explain a high rating were: high per capita income, more rapid growth, low inflation , low ratio of foreign currency debt/exports, absence of a history of defaults and high level of development. The recent

[7] Source: International Monetary Fund, WEO, Crisis in Asia, December 1997, table B7.

history of budget surplus/GDP and current account surplus/GDP were not statistically significant.

The conclusion drawn by the International Monetary Fund study is that: "…spreads as well as market analysts - as represented in Institutional Investor and Euromoney ratings - provided signals similar to those of the credit rating agencies. They failed to signal the Asian crises in advance[8]; they down-graded these countries after their crises".(p. 195).

In summary, with hindsight it is clear that neither the market nor the credit rating agencies anticipated the Asian crises. It is also clear that there is an inadequacy in the standard theories to provide warning signals that identify weaknesses early enough to guide policy makers in either the prevention of crises or in making a rational response to them.

The object of our paper is to provide a coherent theory, which implies quantitatively measurable warning signals of a crisis based upon available information. We draw upon two relatively recent theoretical developments to provide an operational theory to answer:

(a) Was a currency crisis produced by an ***overvalued*** *real exchange rate?*
(b) Was a debt crisis produced by an ***"excessive/unsustainable"*** *external debt?*
(c) What was the ***interaction*** *between the two?*

The phrases in bold letters must be given theoretical and operational content. We use the NATREX model of equilibrium real exchange rates to evaluate whether the exchange rate is misaligned – that is whether the actual exchange rate deviates significantly from its "equilibrium" value thereby precipitating a currency crisis. We use a Stochastic Optimal Control/Dynamic Programming (SOC/DP) approach to derive the optimal foreign debt ratio and we then evaluate the divergence of actual debt from

[8] For example, "In Korea, despite the growing awareness of financial sector vulnerabilities following the collapse of Hanbo Steel in January 1997, there were no actions by the rating agencies until Moody's placed it on negative outlook in June 1997. The downgrade on October 24 by S&P's (from AA- to A+) was accompanied by a sharp rise in yield spreads." In Thailand, "S&P made no rating changes in the period between 1994 and July 1997. No further rating changes occurred during the severe speculative attacks on the baht in May and the subsequent floating of the bhat in July 1997. Interest rate spreads began to rise in the third week of August prior to the downgrade of Thailand's rating by S&P's (to A- on September 3)…"(p. 187)

optimal to see whether the economy is vulnerable to a debt crisis. Both NATREX and SOC/DP have proved to have explanatory power. The aim of this paper is to apply these techniques and concepts to explain the Asian crises, and thereby provide early *warning signals* of a crisis.

3. Currency and Debt Crises: an overview

3.1 Currency Crisis

A currency crisis is generated by an overvalued exchange rate. In order to determine whether a rate is overvalued, we need a definition of an "equilibrium" real exchange rate. We use the concept of the natural real exchange rate (NATREX)[9] which is the rate that satisfies the four conditions (C1)-(C4) below.

(C1) Internal balance prevails where the rate of capacity utilization is equal to its long run stationary mean.

(C2) External balance exists where there are no speculative capital movements or changes in reserves, and domestic and foreign long-term real rates of interest are equal.

(C3) The ratio of net foreign liabilities/GDP is constant.

(C4) As a result of market forces, the actual exchange rate converges to a distribution whose conditional mean is the "equilibrium" rate.

The NATREX theory can be presented graphically. In Figure 1, the current account *CA* is negatively related to the real exchange rate *R*. An appreciation of the currency - rise in *R* - raises domestic production costs and prices relative to foreign production costs and prices. Competitiveness is reduced and the trade balance declines. The saving less investment curve *SI* is positively related to the real exchange rate, because an appreciation of the real exchange rate adversely affects investment. Insofar as goods are sold in the world market, an appreciation of the real exchange rate lowers the

[9] The NATREX was originally presented in Stein, Allen et al (1997). Our exposition here is intuitive and the reader is referred to the basic articles for the formal derivations and analyses. The NATREX model has been shown to have significant explanatory power for the US dollar, the euro, the D-Mark, the Italian Lira, Australian dollar and some Asian currencies. The special issue: "Exchange Rates in Europe and Australasia", Australian Economic Papers, 41 (4) December 2002 contains the basic articles referred to above. The Introduction by Stein and Lim and Stein (2002) and Stein (2002) put the articles into perspective

Tobin q-ratio, which lowers investment. Hence an appreciation of the real exchange rate increases saving less investment. The intersection of the *CA* and *SI* lines gives the determination of the real exchange rate R_0 when conditions (C1) and (C2) are satisfied. We call this the medium run NATREX and it is described algebraically in equation (1)

(1) $R_0 = [R \mid I - S + CA = 0]$

In this case, net savings is negative (the current account deficit is *A* in Figure 1) and hence the foreign debt is rising. Stability is achieved if the rise in the foreign debt stimulates saving, and shifts the *SI* curve to the right. For example, the government may react to a rising public debt by increasing the primary surplus.[10] As saving rises, in response to the accumulation of the debt, the *SI* curve shifts to the right towards *SI**. However, the rise in interest payments on the debt shifts the current account curve to the left towards *CA**. In the long run equilibrium, the real exchange rate converges to *R** in Figure 1, where the ratio of debt/GDP is constant. Condition (C3) implies that the *equilibrium* trade balance to GDP ratio (denoted *B**) divided by the *equilibrium* debt/GDP ratio (*h**) is equal to *(r- g*)* the real interest rate (return on financial assets) less the *equilibrium* growth rate g*. This term must be positive if present values of assets are finite. The *long run* NATREX satisfies conditions (C1)-(C4) and is described by equations (1) and (2).

(2) $B(R^*; Z) = (r - g^*)h^*$

where R^* is the long run NATREX, h^* is the equilibrium debt to GDP ratio. The elements of vector *Z* are the fundamental determinants underlying the S-I and CA functions. They are productivity (υ) and time preference (ρ) measured as the ratio of social consumption/GDP. In Figure 1, the current account/GDP is denoted as *E<0* and the debt to GDP has stabilized at *h**.

[10] This occurs more strongly in the industrial countries than in the emerging market countries; see [IMF, WEO9-2003, p128] for observed relations between these two variables.

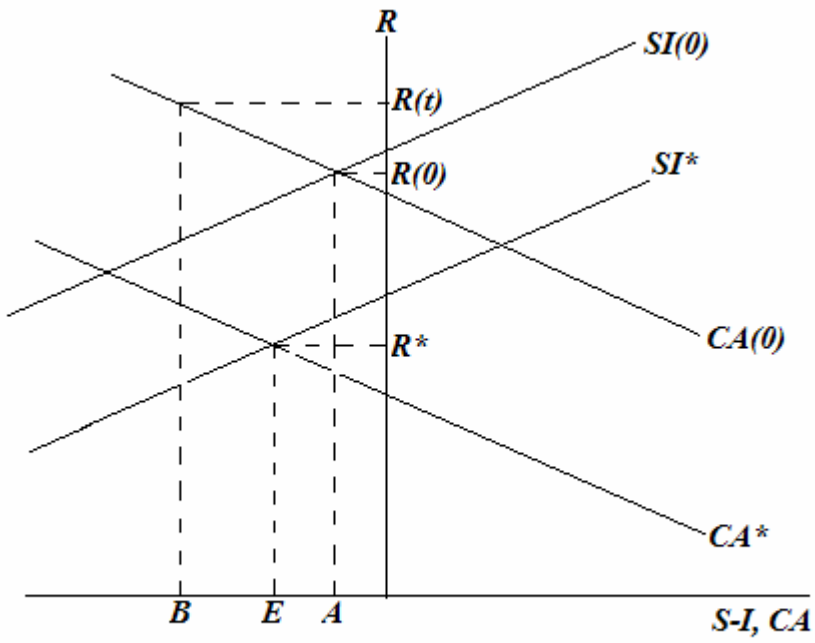

Figure 1. The Medium run and long run real exchange rate NATREX

In the short run, the uncovered "interest rate" parity theory states that the real exchange rate R_t will exceed (be less than) its longer run equilibrium value R^* if the domestic real rate of return on assets i_t exceeds (is less than) the corresponding foreign rate i_t^*.[11] This is denoted as R_t in Figure 1 and mathematically in equation (3). Coefficient α is a speed of response.

(3) $\log(R_t) = \log(R^*) + \alpha(i_t - i_t^*)$

If there is a speculative bubble in asset prices, then the domestic anticipated return i_t rises relative to the foreign rate i_t^*. There is a speculative capital inflow, which appreciates the real exchange rate to R_t above R_0 the medium run equilibrium value. We can think of this inflow as the bank loans and investments in Table 3 during the period

[11] This rate of return could be on fixed income instruments, equity or real property.

1993-96. The net effect is that the current account deficit rises to *B>A,* and the external debt rises at a faster rate.

Real exchange rate R_t is not sustainable for several reasons. First, it can only persist as long as there is a speculative capital inflow. The latter is generated by the differential in rate of return on assets. Insofar as the higher rate of return is generated solely by anticipated capital gains - where asset prices are rising without a corresponding rise in earnings generated - debt service payments are increasing relative to earnings. The bubble must burst, sooner or later. Second, as long as there is a current account deficit, (for example point *B* in Figure 1) due to speculative capital inflow, the debt/GDP and interest payments/GDP will rise. The rise in the debt service reduces the current account, and shifts the *CA* curve to the left along the initial saving less investment curve *SI(0).* The decline in the current account relative to saving less investment depreciates the real exchange rate.

A measure of misalignment ($\Phi_t = R_t - R_t^*$) is the deviation of actual real exchange (R_t) from the equilibrium value (R_t^*). A large value of Φ_t is clearly a warning signal of an impending currency crisis. Furthermore, since the equilibrium value (R_t^*) is related to the set of fundamental variables Z_t, we can also explain the cause of the misalignment. In section 4, we examine how well this measure identified periods of overvaluation, and hence how well this measure served as a warning signal of a currency crisis for the Asian countries.

3.2 Debt Crisis

A currency crisis is likely to result when the actual real exchange rate exceeds the benchmark exchange rate- the NATREX – for a considerable period of time. Similarly, a debt crisis is likely to occur when actual external debt is excessive or "unsustainable". In order to assess whether the debt is "unsustainable" we need a concept of an optimal debt as our benchmark. Excess debt can then be measured as the deviation of the actual debt

from the optimal debt. Our concept of an optimal debt draws upon our recent work on stochastic optimal control/dynamic programming analysis of optimal debt[12].

The country will have a debt crisis if the attempt to service the debt requires a decline in consumption below a tolerable level, or requires a drastic decline in consumption. To see this first consider equation (4) which describes the change in the debt dL_t, where L is the real external debt.

(4) $dL_t = (I_t - S_t)dt = (C_t + I_t + r_t L_t - Y_t)dt$

It arises because consumption C_t plus investment I_t plus the debt service $r_t L_t$ exceeds Y_t the GDP. Alternatively, the change in the debt is $(I_t - S_t)dt$ investment less saving over the period. In the Latin American countries the debt has risen due to high consumption and/or low social saving by the public plus the private sectors. In the Asian countries, the high investment has produced the external debt. For example, there were speculative bubbles in asset prices for land and/or equity that raise the anticipated returns. The differential investment less saving leads to a capital inflow and an increase in the external debt.

The external debt has to be serviced and that would clearly affect consumption. We can see this by writing consumption at some time after t, say at time $s=t+\Delta t$, equation (5) below.

(5) $C_s dt = (Y_s - r_s L_s - I_s)dt + dL_t$

Consumption is equal to the GNP, which is equal to the GDP less the debt service $(Y_s - r_s L_s)$, less investment I_t plus new borrowing dL_t.

Focus now on the behavior of the two stochastic variables - real GDP and real interest rate. If bad shocks reduce the GDP and raise real interest rates, and investment

[12] The analysis is based upon Fleming-Stein (2004), Stein (2004) and Fleming (2004). The reader is referred to these papers for the technical details and proofs. This analysis was used by Stein (2004) to explain the US farm debt crisis of the 1980s.

falls to a minimum level $I_s = I_{min}$ then consumption may have to be reduced - unless there is new borrowing to offset the decline[13]. In the event that new borrowing is not forthcoming, we may expect a debt crisis because it is more likely that the *country would renegotiate its debt than reduce consumption.*

To formalize the discussion we model the two sources of uncertainty which affect consumption. The first source of uncertainty is the growth of GDP described in equation (6) below.

(6) $dY_t / Y_t = b\, I_t / Y_t\, dt + \sigma_y\, dw_y$

Real growth dY_t / Y_t has two components: a deterministic component bI_t / Y_t where b is the mean return on investment times I_t/Y_t the ratio of investment/GDP, and a stochastic component involving the variance of output $\sigma_y^2 dt$. This stochastic part may be viewed as arising from variations in the terms of trade, the conditions of aggregate demand and the composition and quality of the investments.

The second source of uncertainty concerns the real interest rate required to service the external debt L_t. The real interest rate in terms of consumer goods r_t has three components. The first is the real interest rate on US Treasury long term debt. The second is the premium on dollar denominated debt charged to sovereign borrowers. The third is the anticipated exchange rate depreciation of the currency. Equation (7) is the equation for the real debt service, where the first term is deterministic and the second term is stochastic. Each component varies and produces a variance of $(\sigma_r L_t)^2\, dt$ on the real debt service.

(7) $r_t L_t dt = r L_t dt + \sigma_t L_t dw_r$

Each source of uncertainty is modeled as a Brownian Motion. Each expectation of dw_y and dw_r is equal to zero, but they are correlated. During the Asian crisis period, the

[13] In Korea, the investment/GDP ratio fell from 35% in 1997 to 21% in 1998. In Thailand the investment ratio fell from 41% in 1996 to 22% in 1998.

growth of GDP and real interest rate were negatively correlated and that can be explained briefly as follows.

A decline in GDP may occur because of a decline in the terms of trade and/or the anticipated return on investment turns out to be an illusion and the asset bubble collapses, $dw_y < 0$. Since firms borrow primarily from the banks to finance real investment and the banks in turn primarily finance their loans by borrowing US dollars in the international capital market, a domino effect is created in the event of a financial panic. When debtors are unable to repay their loans to the banks, the banks in turn become unable to repay their loans to international creditors. Financial panic leads to a short term capital flight. The government may try to help out by using the dollar reserves, but that is only a stopgap measure. Sooner or later the monetary authorities will raise interest rates and, when that fails to stem the outflow, the currency will suffer a devaluation/depreciation. The depreciation of the currency implies that the real rate of interest, measured in terms of the prices of goods produced, rises ($dw_r > 0$). The situation is exacerbated when banks denominate their loans to the domestic firms in US dollars. Firms would find it very difficult to service debts denominated in foreign currency because they are faced with both a rising rate of interest and a depreciating currency.

Faced with these sources of uncertainty, how then should a country select its optimal debt and level of consumption to maximize the expectation of the discounted value of the utility of consumption over an infinite or finite horizon? The intertemporal nature of the process is seen in equations (4) and (5). A rise in the debt at one time will affect consumption at a later date. The standard approach in the economics literature is to maximize the expectation of the discounted value of the utility of consumption subject to an "Intertemporal Budget Constraint" **IBC.** The **IBC** requires that the expectation of the discounted value of consumption be equal to the expectation of the discounted value of GDP.

Given the uncertainty concerning the growth rate (equation 6) and real interest rate (equation 7), the future is unpredictable. *The IBC is unknowable and unenforceable*. How can anyone know if any country is, or is not, violating the constraint? *The IBC is a non-operational concept*. This profound deficiency of the **IBC** approach led Fleming and

Stein to use dynamic programming **DP** approach[14]. The controls are the debt and consumption. The optimal controls are functions of the state of the system, which are observable/measurable variables.

As shown in Fleming-Stein (2004) and Stein (2004), the solution for the optimal ratio of debt/net worth is equation (8). Only an intuitive explanation is presented here. Using Stochastic Optimal Control/Dynamic Programming we derive the optimal ratio *f** of debt/net worth[15]. The derived optimal debt in equation (8) is a benchmark measure of performance.

(8) $f^* = (b-r)/(1-\gamma)\sigma^2 + f(0)$, $\sigma^2 = var\ (dY_t/Y_t - r_t)$,

where *b* is the *mean* return to investment (in equation 6), *r* is *mean* real interest rate (in equation 7), quantity $(1 - \gamma)$ is a measure of risk aversion and σ^2 is the variance of the quantity $(dY_t/Y_t - r_t)$, the current growth rate less the current interest rate, so that it also contains a covariance term. Equation (8) is graphed in Figure 2 as line *US*.

The optimum ratio of debt/net worth, *f** is positively related to the *mean* rate of return on investment less the *mean* real rate of interest *(b-r)*. The slope is the reciprocal of the product of risk aversion and risk. The intercept *f(0)* is the optimal ratio of debt/net worth, when the expected net return *(b-r) = 0*. When the correlation coefficient between the growth rate and interest rate is less than σ_y / σ_r, the intercept $f(0)<0$. Any nonpositive correlation implies $f(0) < 0$ as drawn in Figure 2. The country should be a debtor only when the net return $(b-r)>A>0$, where A is the risk premium implied by equation (8).

[14] The DP approach is used in mathematical finance, starting from the work of Robert Merton.

[15] Net worth is "capital" less debt. Capital is the Frank Knight concept, the discounted value of current income, Y_t/b, where Y_t is current GDP and b is the mean return on investment in equation (6). This is a measurable and logical concept. The ratio of h_t = debt/GDP is positively related to the ratio of f_t = debt/net worth. Therefore, we can speak about either ratio *f* or *h* interchangeably. The optimum ratio of consumption/net worth is constant, $c^* = C_t/X_t$. Therefore consumption, net worth and GDP grow at the same rate.

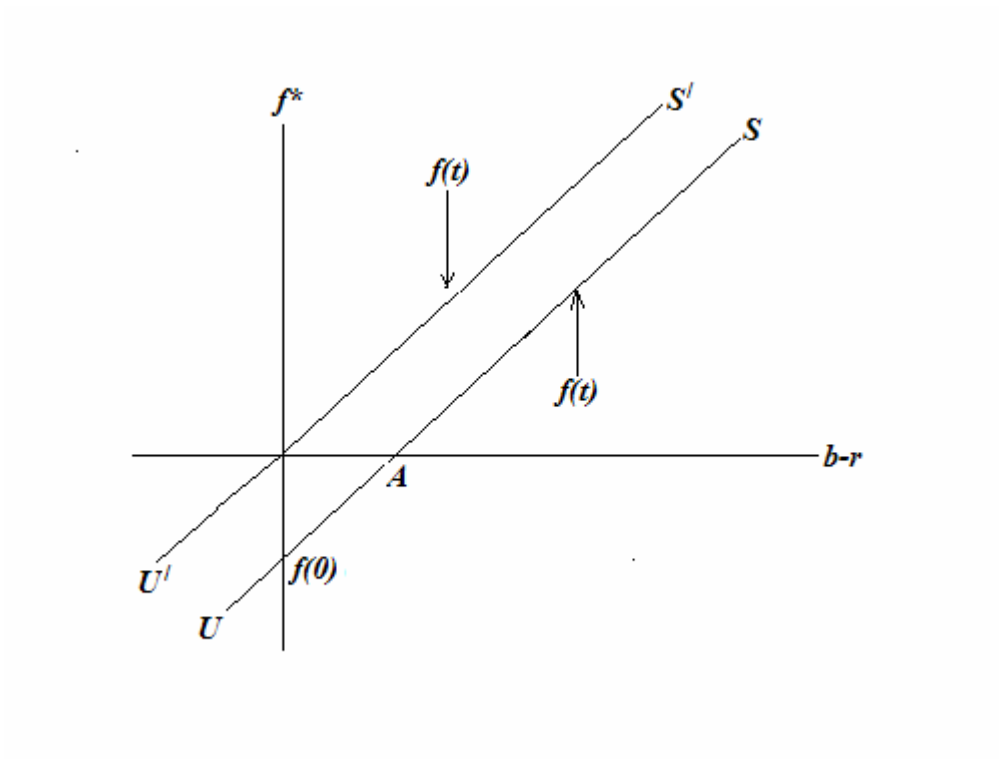

Figure 2. Optimal Ratio Debt/Net Worth f^*
curve US , when there are no liquidation costs and curve $U'S'$ with liquidation costs

Curve US is the optimal ratio, if there were no transactions or liquidation costs in selling capital to repay debt. When there are transactions/liquidation costs of selling capital to repay debt, there is another line $U'S'$ above US. The optimal control is as follows: (i) if the debt/net worth is above $U'S'$, lower it immediately to this line; (ii) if the debt/net worth is below US, raise it immediately to this line; (iii) if the debt/net worth is between the two lines, do nothing. Most of the time, the optimal debt ratio will lie in the region between the curves. The proof of these statements is difficult[16], but the intuition can be conveyed. As the net worth changes drastically and very frequently due to the Brownian motion, given the same mean net return (b-r), the capital should be bought and sold to keep the debt ratio constant given by line US. The sales of the capital to repay the debt would have to occur at "fire sale" prices. Then, as net worth rises again due to the Brownian motion, the capital would have to be repurchased with new debt. All

[16] The references to the proofs in the mathematical literature, especially by Davis and Norman, Fleming and Soner, is in Stein (2004).

of these sell-buy transactions involve significant costs. Such a process would quickly dissipate the net worth. The optimum control is not to vary the capital or debt unless the ratio is sufficiently far from the optimal to justify the huge liquidation costs. In the graph, we assumed that there were only "liquidation costs" and not costs of acquisition. Therefore, only if the debt ratio is above U'S' should the ratio be reduced. Even then, it should only be reduced to U'S' and not to US. The difference between these curves is a complicated function of the liquidation costs.

The optimum debt ratio, our benchmark of performance, has several important characteristics. It is the value where: (i) The expected present value of the utility of consumption is maximized, (ii) the expected growth rate - of consumption, net worth and GDP - is maximized[17]. The major implications of the analysis are as follows.

- As the debt ratio rises above the optimum f^*, the expected growth rate declines, and the risk - the variance of the growth rate increases.
- Since optimal consumption is proportional to net worth, as the debt ratio rises above the optimum, the expected growth of consumption declines and its variance rises. The probability of a decline in consumption increases and the probability of a debt crisis increases.
- Insofar as there are liquidation costs in selling capital to repay debt, the optimal ratio should lie between lines *US* and *U'S'* in Figure 2, where the difference is a function of liquidation costs.

In summary, when the net return *(b-r)* is falling and the debt/GDP ratio is rising, it is more probable that the debt ratio is in the region above the curve *U'S'*. Hence divergent movements of the net return *(b-r)* and the debt/GDP ratio can serve as an operational warning signal that foreign debt is becoming "excessive"[18] and that the

[17] This is true in the case of the logarithmic utility function.

[18] The stochastic optimal control approach to deriving a benchmark for the optimal debt is conditional upon the model and the stochastic processes. In the model above, we assumed that the debt was long term at a variable interest rate. Thus there were two shocks, which were correlated. On the other hand in Stein-Paladino (2001), based upon Fleming-Stein (2001), the model assumed that debt was short term foreign currency debt that must be repaid at the end of the period, such as the category "Bank loans, investments" in table 3 above. The stochastic variable was the return on investment, variable b_t. The "bad" state of nature is a value of the return below the interest rate. We calculated both an optimal debt/GDP ratio and a maximal ratio of debt/GDP called *debt-max*. If the debt exceeded the *debt-max* then - if the "bad" state of nature occurs - consumption would have to be reduced below a tolerable level and the country would

economy is becoming susceptible to default. In section 4, we examine the time-paths of actual debt/GDP ratios relative to the time-paths of their *(b-r)* values to explain the pattern of debt defaults during the period of the Asian financial crisis.

4. Empirical Analysis

Section 4.1 discusses whether the Asian currencies were overvalued, and section 4.2 discusses whether they had excessive debt. Table 6 below summarizes the results. In the conclusion part 5, we explain the interaction of these two sources of crisis. The reader may want to look at this table while reading these two parts.

4.1 Were the Asian Currencies overvalued?

In this section, we examine the proposition that the nominal exchange rate depreciated in 1997, because the real exchange rate (R_t) was overvalued relative to the equilibrium rate suggested by NATREX. The real exchange rate R_t is defined as $R_t = N_t(P_t / P_t^*)$ where the nominal rate *N* is defined as the number of *$US* per domestic currency (a rise is an appreciation), and *P (P*)* is the domestic (foreign) price index. The currencies of Thailand, Malaysia, Philippines and Indonesia were linked to the US dollar, which appreciated from 1995-98 relative to both the Japanese Yen and to a trade weighted index. Misalignment would occur if the actual real exchange rate deviated significantly from the NATREX suggested rate.

Following the discussion above, we estimate the deviation of the actual rate from the NATREX equilibrium rate as our measure of the degree of over and under valuation, i.e., "misalignment". To compute our empirical measure of misalignment, first recognize that misalignment $\Phi_t = R_t - R_t^*$ can be rewritten as $\Phi_t = (R_t - R_{t-1}) - (R_t^* - R_{t-1})$. The first term is the actual change in the exchange rate. The second term can be written as:

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default. In the empirical work, the debt was the total sovereign debt to both sovereign and private creditors, denominated in US dollars. We used as our Warning Signal the difference DEF = [(debt/GDP) - (debt-max)]. Stein-Paladino showed that the actual debt ratio was not able to explain default. On the other hand, a *sufficient condition* for rescheduling/default was that DEF > 0, the debt ratio exceed (debt-max). A second Warning Signal of an excessive debt is that DEF > 0 and/or rising significantly.

$(R_t^* - R_{t-1}) = (R_t^* - R_{t-1}^*) + (R_{t-1}^* - R_{t-1})$. Term $(R_t^* - R_{t-1}^*) = \alpha \Delta Z_t$ is the change in the NATREX based upon changes in the fundamentals in vector Z, and term $(R_{t-1}^* - R_{t-1}) = \varepsilon_t$. Thus term $(R_t^* - R_{t-1}) = \alpha \Delta Z_t + \varepsilon_t$. Then use *recursive least squares* to estimate the coefficient α in the regression equation $\Delta R_t = \alpha_t \Delta Z_t + \varepsilon_t$. Finally compute misalignment $\Phi_t = R_t - R_t^*$ as:

(9) $\Phi_t = \Delta R_t - \hat{\alpha}_{t-1} \Delta Z_t$

Vector *Z* contains three fundamental variables:[19] productivity (υ), time-preference[20] (ρ) measured as the ratio consumption/GDP - which is negative thrift, and the differential of long-term real net return (*b-r). The b is the domestic real return and r reflects the cost of capital.* Our method of estimation avoids the problems associated with non-stationary time-series data and more importantly, the coefficients contained in the vector $\hat{\alpha}_{t-1}$ are estimated by recursive least squares and hence are based only on information up to time t. *Post-crisis information is not used before the event to predict the event.* As presented above, Φ_t may be interpreted as the deviation of the actual change in the real exchange rates from the change that should prevail at time t, given changes in the explanatory variables, ΔZ_t suggested by NATREX.[21] Note however that Φ_t is an estimate of the difference between the level of actual R_t and the NATREX estimated R_t*.

Productivity (υ) is measured as real GDP per capita and time preference (ρ) is the ratio of household and government consumption expenditure per GDP. The real return to investment expenditure (*b)* is computed as the (growth rate of GDP)/(investment/GDP). The long term real return *r* is the 10-year US bond rate less US inflation[22]. These variables are all readily available from the IMF, International Financial Statistics.

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[19] We also tested a terms of trade variable, but they were not always significant.

[20] From SOC/DP analysis the optimal ratio of consumption/net worth is the discount rate, when a logarithmic utility function is used; See Fleming and Stein (2004).

[21] Note that, this approach avoids a problem associated with estimation over the whole sample period and then defining the residuals of a regression model as a measure of misalignment. Here post-crisis information is not used before the event to predict the event.

[22] The real interest rate should take into account the anticipated depreciation of the currency. Since the exchange rates were linked to the $US, the market did not take the likelihood of depreciation into account.

Charts 1-5 present our analysis for the ASEAN 4 countries (Indonesia, Malaysia, Philippines, Thailand) plus Korea. The *pre-crisis period 1994-96 is shaded*.

Each chart shows a plot of the deviations of the level of the actual rate from the NATREX rate (expressed in standardised units, that is in the form: $\left[\Phi_t - mean(\Phi_t)\right] / std(\Phi_t)$) as well as information about the explanatory variables $\Delta\upsilon$, $\Delta\rho$ and *(b-r)* pre, during and post crisis. Recall that the NATREX is a positive concept - the real exchange rate satisfying conditions (C1)-(C4) above - and not a normative concept such as Williamson's FEER.

The crisis started in *Thailand*, whose currency was linked to the $US which was appreciating relative to the Yen and other major currencies. As shown in the charts, Thailand is the country with the prolonged pre-crisis period of misalignment from about 1990 to 1995/96. The decline in productivity, increase in the propensity to consume, plus decline in relative return – all signaled that a depreciation of the nominal exchange rate (given sticky prices) was necessary to realign the real exchange rate. Deviation Φ_t is a warning signal of misalignment.[23]

The signals for Korea were the same as for Thailand, but in this case the exchange rate was not seriously misaligned. A crucial variable that is common to both the Misalignment and excess debt is the net rate of return on investment. In both Thailand and Korea, the net return *(b-r)* declined drastically from 1995 to 1997. This means that the medium run equilibrium exchange rate should be falling from R_t towards R* in figure 1. Thereby we have warning signals of exchange rate misalignment for Thailand and Korea.

In contrast, over the period 1981-96 the Indonesia rupiah was aligned with the NATREX rate and there were no signals, based upon trends of productivity, time-preference or returns, that the currency was misaligned. Malaysia and the Philippines, show no prolonged periods of misalignment. In fact the pre-crisis signals, such as a decrease in the propensity to consume, supported the appreciation then underway.

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[23] Rajan, Sen and Siregar (2002) conducted an **ex-post study** of the Baht's misalignment with respect to the Japanese Yen since Thailand's main trading partner was Japan, which was also the major creditor. They concluded that it was relatively larger than that for the $US and that the misalignment with respect to the Yen is consistent with a widening of the Thai trade deficits before the crisis.

4.2 Were the Asian foreign debts unsustainable?

Following the discussion in section 3.2, our strategy is to compare the evolution of the actual debt/GDP ratios *h* with the evolution of the relative returns (*b-r)* on investment in the Asian countries. If the relative return is declining significantly but the debt ratio is rising significantly or not declining, then the debt ratio is moving into the region above the line *U'S'* and the probability of default increases for the following reason. Growth is expected to decline and the variance/risk to rise. For any consumption ratio, a decline in expected growth and a rise in its variance will augur a decline in consumption and hence a debt crisis. *A sufficient condition for a crisis is a strong decline in the relative net return and a rise or at least not a decline in the debt ratio.*

We know, with hindsight that the Asian countries that defaulted were Indonesia (1998), Korea (1998) and the Philippines (1984-96) and the countries that did not default were Malaysia and Thailand. We now explore whether our suggested warning signal variables *h* and (*b-r)* for *Korea* would have indicated the likelihood of default whereas the signals for *Malaysia* would have indicated no financial vulnerability.

For each country, h_t is the actual debt/GDP ratio based on data published by the Economic Intelligence Unit. The debt is total external debt stock "comprising public and publicly guaranteed long term debt, private non-guaranteed debt, use of IMF credit and short term debt, end of period". The net return (*b-r)* is as defined above. Again, these are publicly available data and subjected to no manipulations. The plots of h_t and $(b-r)_t$ are shown in Charts 1-5. The *pre-crisis period 1994-96 is shaded*.

The return b_t varied significantly, but the interest rate spread and credit ratings were practically constant until the crises, as noted above. Therefore, any anticipated exchange rate depreciation was not reflected in the cost of capital. Variations in $(b_t - r_t)$ are almost exclusively due to variations in the return on investment b_t. We do not arbitrarily select a comparison period, rather we use the information contained in the two time series. When they diverge in the manner described above, we anticipate a crisis. The data are annual, which irons out random fluctuations.

Korea and *Thailand* both gave warning signals that they were incurring excess debt. In both cases, prior to the crisis, there was a clear upswing in the debt/gdp ratio and

a clear downswing in relative returns. Industrial policy in *Korea* involving the government, the banks and the "chaebols" aimed for rapid growth with little concern for the rate of return *b* on investment. The banks were used as the means to finance the growth. The banks were not concerned about the risk, because there was an implicit government guarantee. That is why the total external debt ratio rose, even though the net returns were declining. In *Thailand*, the net return declined from 12% pa in 1994 to 4.77% pa in 1996 (see chart 5), but the external debt rose by 40% during that period. Rajan, Sen and Siregar show that half of the debt was short-term, 45%, was denominated in Yen and Japanese banks were the major creditors.

Warning signals for Korea and Thailand mean that the expected growth of consumption was low and its variance was high. Any random event could lead to a debt crisis, where the economy could not service its debt without reducing consumption. Such random events were the bankruptcies of major Korean concerns in 1997 before the crisis, and the collapse of the bubble in the construction sector in Thailand that led to bank failures[24].

Whereas Korea and Thailand both showed Warning Signals of an excess debt, in Malaysia, Indonesia and the Philippines there was no evidence that the debt ratio was "excessive" in the pre-crisis period 1994-96. However for the Philippines, there were clear Warning Signals of the debt crises period 1984-94.

5. Conclusions: Interactions of types of crisis

Much has been written, with hindsight, about the causes of the Asian financial crisis. The crises were unexpected by the market and many countries in the region experienced it at about the same time. The traditional warning signals in use then[25] were inadequate. To this end, we analyzed the Asian financial crisis from two related perspectives - whether the crisis was precipitated by a failure of the real exchange rate to

[24] See Flouzat, chapter 2 and Rajan, Sen and Siregar for stimulating discussions of the developments in the Asian countries.

[25] These signals were the budget deficit, inflation and current account deficit. Table 2 shows that they were inadequate.

be aligned with its fundamental determinants, and/or whether the crisis was precipitated by a divergence of the foreign debt from its optimal path. Our models produced a set of objective, theoretically based warning signals and our empirical analysis allowed us to assess whether there were signs of financial distress before the crisis.

Table 6 presents a summary of the warning signals, based upon Charts 1-5. *Our warning signals and measures of misalignment are based upon available information before the crisis.* In all of these countries during the crisis, the exchange rate depreciated and the GDP declined significantly, as shown in Table 1.

The two types of crises are inter-related. In both cases, *the level of either the real exchange rate or the debt is irrelevant.* The relevant variables are: (a) the *Misalignment* $\Phi(t)$ of the real exchange rate from the NATREX in figure 1, and (b) the *deviation* of the debt ratio from its optimal level - if the debt ratio has risen above curve U'S' in figure 2.

A currency crisis may lead to a debt crisis in the following way. In figure 1, the exchange rate R_t is overvalued relative to the longer run NATREX R^*, because a speculative/unsustainable bubble led to a differential anticipated rate of return on assets. Capital inflows raise the debt. Initially the inflow is 0B per unit of time. When the anticipated return turns out to be an illusion, such as in Korea and Thailand, the capital inflows will not continue at the same level and the real exchange rate will fall drastically to a lower NATREX. If the nominal exchange rate is free, there will be exchange rate depreciation and the real interest rate - measured in terms of the GDP deflator - on the foreign debt will rise. If the nominal exchange rate is pegged, reserves will decline. The monetary authorities may raise interest rates. Eventually, the currency will be depreciated. In either case, real interest rates rise. If the debt is sufficiently high, then term r_sL_s in equation (5) will rise drastically and tend to reduce consumption C_s in equation (5). Moreover when the exchange rate depreciates, there may also be a capital outflow - term dL_t falls.

Once the exchange rate collapses, it is easy to understand why defaults may occur. The collapse of the exchange rate raises the cost of servicing the foreign debt, which leads to bankruptcies and financial market stringency. As a result, the country is thrown into a recession when the GDP falls. Even though the level of the debt has been relatively stable, the decline in the GDP raises the debt/GDP ratio. The attempt to service

the debt would reduce consumption below a tolerable level and the country will default. In this way, a currency crisis may lead to a debt crisis. If the value of r_sL_s is not too high, then misalignment $\Phi(t)$ will only generate a currency crisis.

A *debt crisis* occurs with positive probability when the debt ratio has risen above the *U'S'* curve. A rise in the debt ratio occurs if there have been sustained capital inflows, current account deficits. If the debt ratio rises along curve US because of rises in (b-r), the rise in the debt ratio is optimal. Therefore current account deficits or rises in the debt *per se* do not imply that there will be a crisis. Table 5 shows that the debt service/exports did not rise in the Asian countries before the crisis. However, there cannot be a debt crisis without a prior rise in the debt. It is not revealing to state that current account deficits lead to a debt crisis.

However, if the debt ratio tends to rise above curve *U'S'* in figure 2, then the situation is unstable. Any random event - decline in Y_t or a rise in r_t - can generate a debt crisis. Once the country is unable to service the debt, then there will be a capital outflow, particularly short term capital. See net private capital flows: bank loans and investments from 1995-98 in table 3. As a result of these outflows, the exchange rate collapses. In this way a debt crisis leads to a currency crisis.

Our analysis focuses upon two countries: Thailand and Korea. Table 6 suggests that *Thailand* was primed for a collapse of the currency. Its exchange rate was severely misaligned and its foreign debt was sub-optimal. The warning signs for *Korea* were the same as for *Thailand* – consumption was increasing at a time of falling productivity and relative returns. The Korean exchange rate was not severely misaligned, but there were clear Warning Signals and the financial crisis took the form of a debt crisis.

Our analysis did not find objective warning signals of the 1997-98 crises for Indonesia, Malaysia and Philippines. There were no declines in productivity or in the differential returns prior to the crisis. The situation for *Indonesia*, *Malaysia,* and the *Philippines* may be symptomatic of a "contagious effect". When the crises occurred in Thailand and Korea, because the situations were not sustainable in terms of our objective criteria, the Japanese commercial banks - which were the common lender - raised risk premia for loans to the other countries in the region. The Japanese banks tried to reduce

their risk exposure to the other borrowers. Short term capital flowed out of the other Asian countries and their exchange rates depreciated.

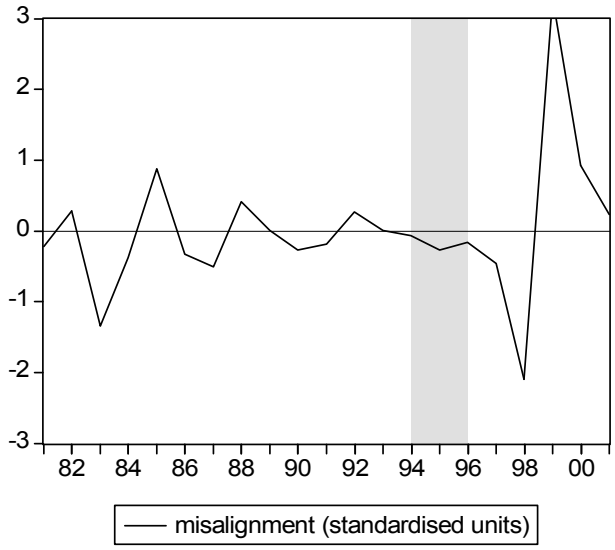
The "contagion" argument is a description rather than a precise analytical concept[26]. Rajan and Siregar (2002) compared the experiences of Hong Kong with those of Singapore. They are similar economies, subject to similar shocks. The main difference between them is the flexibility of the exchange rate to real shocks - our fundamentals discussed in part 4. The Hong Kong currency was linked to the $US via a currency board. The Singapore currency was much more flexible. Rajan and Siregar estimated the NATREX for each economy and then examined **ex-post**, the degree of misalignment. They found that, in the period leading up to the crisis, the Hong Kong currency was misaligned, whereas the Singapore dollar was not. When the Asian crises occurred, the Hong Kong growth rate fell severely from 5.15% pa in 1997 to -5 % p.a. in 1998. In Singapore the growth rate declined from 8.8% to 0.5%, a significantly better performance than in Hong Kong. A message here seems to be that “contagion” can be mitigated by avoiding exchange rate misalignment and by adopting a more flexible exchange rate system.

[26] There is a large literature on "contagion"; see Kaminsky et al.

Table 6: Summary of Warning Signals Analysis for 1997-98 Crises

Country	Actual Changes	Analysis of Misalignments pre-crisis	Warning Signals of excessive debt during pre-crisis period
Indonesia	Rupiah depreciated and debt **defaulted 1998**	No evidence of significant misalignment	No warning signals
Korea	Won depreciated debt **defaulted 1998**	No evidence of significant Misalignment	**Warning Signals**. Evidence of growing debt/GDP ratio despite falling excess returns
Malaysia	Ringgit depreciated but there was no debt default	Evidence of misalignment, but not prolonged	No Warning Signals
Philippines	Peso depreciated debt **defaulted 1984,1986,1987, 1990,1991,1992, 1994**	Evidence of misalignment, but not prolonged	No Warning Signals (Warning signals for 1984 default)
Thailand	Baht depreciated but there was no debt default	Evidence of **prolonged, persistent misalignment**	**Warning Signals** Growing debt/GDP ratio despite falling net returns

Chart 1: INDONESIA



Warning Signal Variables: Pre, During and Post Crisis (Indonesia)

	Δυ (%)	Δρ (%)	(b-r) %
1994	5.72	0.39	13.68
1995	6.39	2.35	14.96
1996	6.06	0.74	14.21
1997	3.16	-2.04	5.67
1998	-15.47	6.99	-104.57
1999	-0.58	9.19	-18.06
2000	3.44	-7.42	15.69
2001	1.95	-0.44	2.07

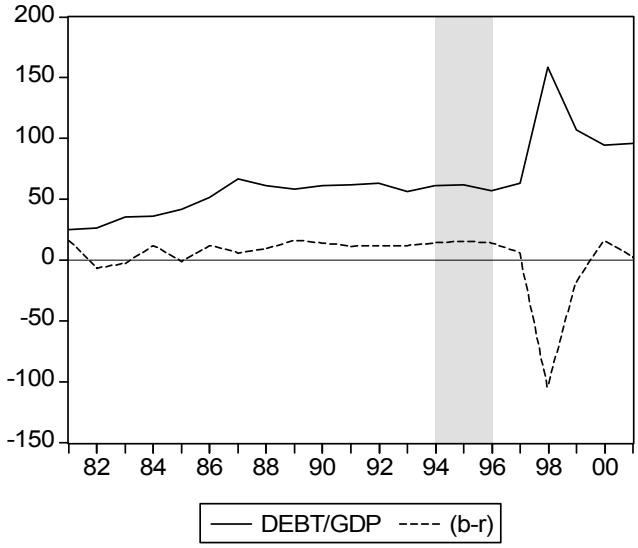
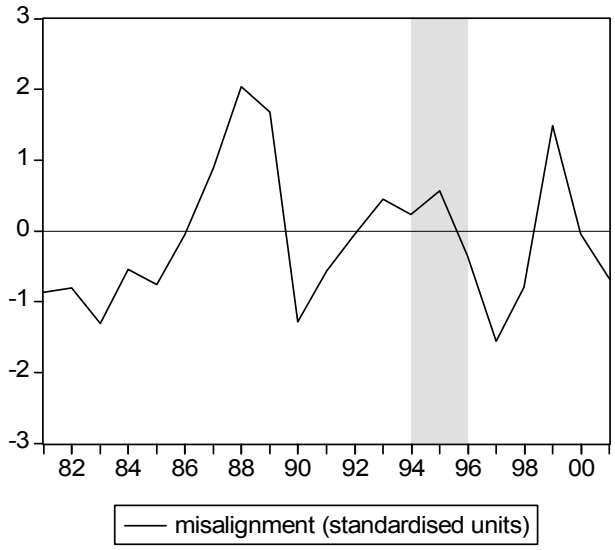


Chart 2: KOREA



Warning Signal Variables: Pre, During and Post Crisis (Korea)

	Δυ (%)	Δρ (%)	(b-r) %
1994	6.94	0.93	11.50
1995	7.61	-0.34	15.13
1996	5.65	2.50	9.34
1997	4.06	0.52	5.58
1998	-7.70	-1.06	-34.24
1999	9.60	1.39	32.91
2000	8.22	1.22	26.47
2001	2.40	3.14	5.12

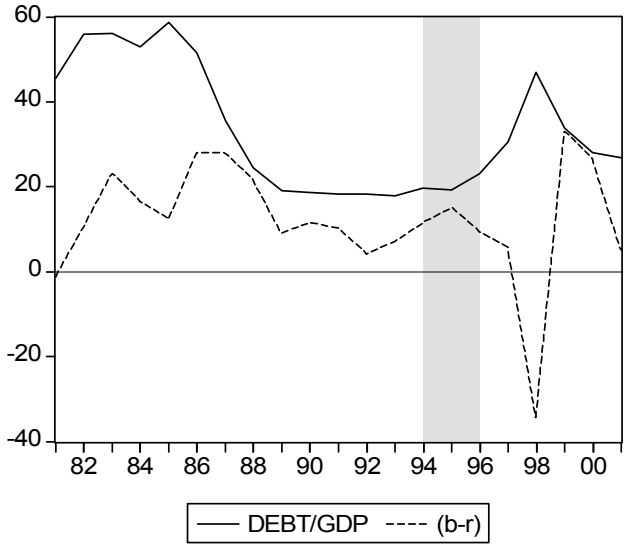
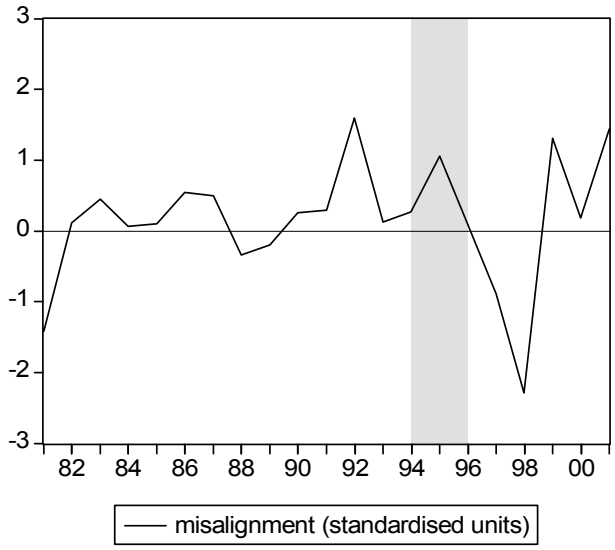


Chart 3: MALAYSIA



Warning Signal Variables: Pre, During and Post Crisis (Malaysia)

	$\Delta\upsilon$ (%)	$\Delta\rho$ (%)	(b-r) %
1994	6.17	-0.84	13.73
1995	6.77	-0.18	14.30
1996	6.96	-5.38	15.45
1997	4.53	-1.81	9.72
1998	-10.11	-8.91	-37.35
1999	3.59	2.38	21.03
2000	5.76	0.52	27.02
2001	-1.66	8.72	-1.84

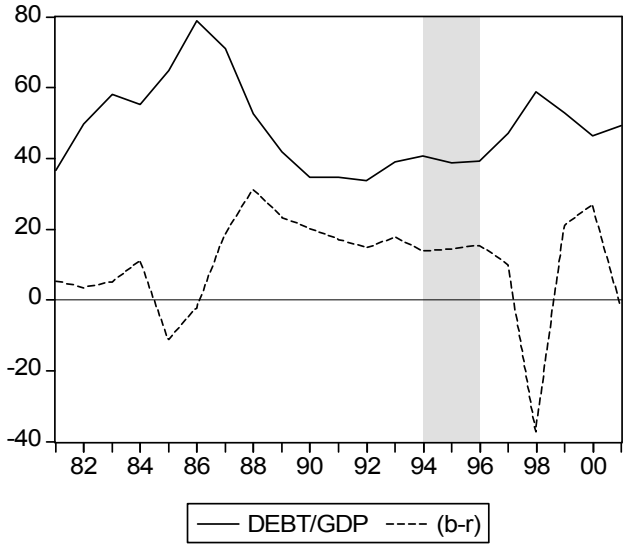
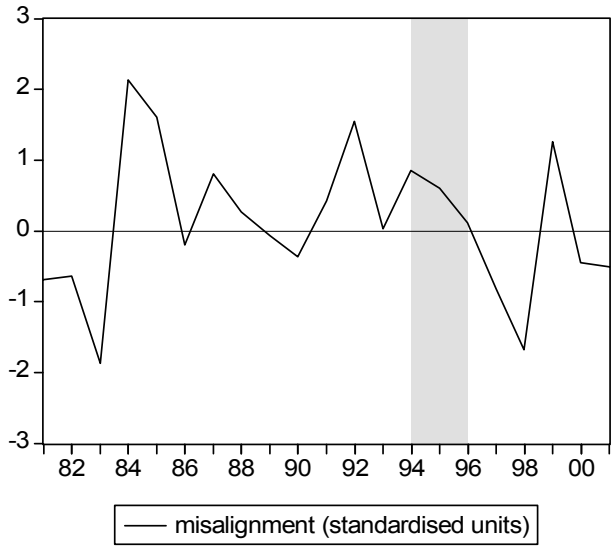


Chart 4: PHILIPPINES



Warning Signal Variables: Pre, During and Post Crisis (Philippines)

	Δυ (%)	Δρ (%)	(b-r) %
1994	2.07	-1.27	5.63
1995	2.39	0.37	9.08
1996	3.55	-0.07	12.06
1997	2.97	0.45	10.97
1998	-2.61	2.08	-15.73
1999	1.36	-2.20	7.53
2000	1.99	-3.55	11.58
2001	1.46	-0.94	8.89

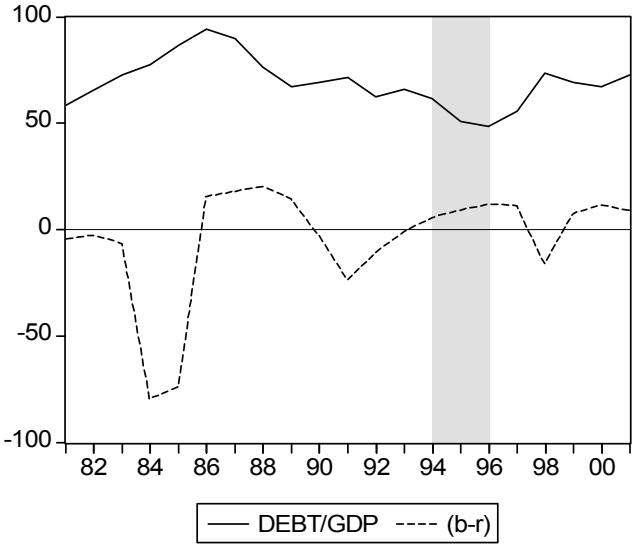
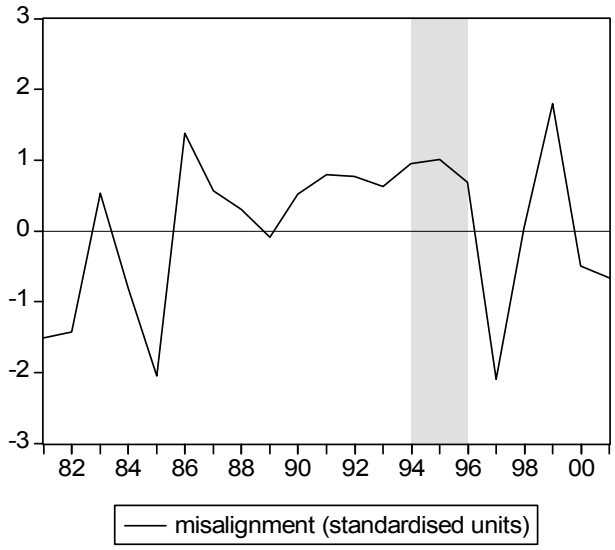
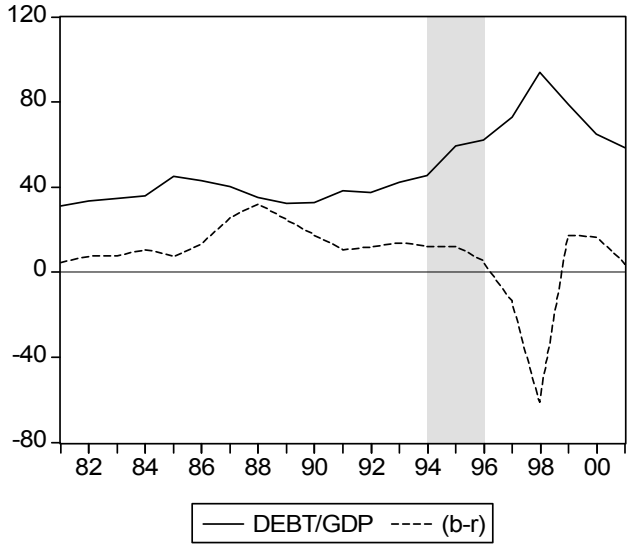


Chart 5: THAILAND



Warning Signal Variables: Pre, During and Post Crisis (Thailand)

	Δυ (%)	Δρ (%)	(b-r) %
1994	7.42	-1.44	12.11
1995	7.69	-1.05	12.06
1996	4.64	1.41	4.77
1997	-0.02	1.20	-13.59
1998	-0.12	0.73	-61.10
1999	0.03	3.39	17.03
2000	0.03	-0.19	16.39
2001	0.01	1.63	3.87



REFERENCES

Arteta, Carlos (2003) Are Financially Dollarized Countries More Prone to Costly Crises? International Finance Discussion Papers, 763, Board of Governors Federal Reserve System, March

Berg, Andrew and Catherine Pattillo (1999) Are Currency Crises Predictable? International Monetary Fund, Staff Papers, June

Dean, James (2001) East Asia Through a Glass Darkly, in Geoffrey Harcourt et al (ed), Essays in Honour of Mark Perlman, Routledge.

Fleming,Wendell H. and Jerome L. Stein, (2004), *Stochastic Optimal Control, International Finance and Debt*, Journal of Banking and Finance.

Fleming,Wendell H.and Jerome L. Stein, (2001), *Stochastic Inter-temporal Optimization in Discrete Time*, in Negishi,Takashi, Rama Ramachandran and Kazuo Mino (ed) Economic Theory, Dynamics and Markets: Essays in Honor of Ryuzo Sato, Kluwer, Boston.

Fleming,Wendell H. (2004) Some Optimal Investment, Production and Consumption Models, American Mathematical Society, Contemporary Mathematics.

Flouzat, Denise (1999) La nouvelle emergence de l'Asie, l'évolution économique des pays asiatiques depuis la crise de 1997, Presses Universitaires de France

International Monetary Fund, World Economic Outlook (WEO), Financial Crises, May 1998, Washington DC

International Monetary Fund, World Economic Outlook (WEO), Financial Turbulence in the World Economy, October 1998, Washington DC

International Monetary Fund, World Economic Outlook (WEO), Public Debt in Emerging Markets, September 2003, Washington DC

Kaminsky, Graciela, Carmen M. Reinhart and Carlos A. Vegh (2003), The Unholy Trinity of Financial Contagion, Journal of Economic Perspectives, 17 (4).

Rajan, Ramkishen and Reza Siregar (2002) Choice of Exchange Rate Regime: Currency Board (Hong Kong) or Monitoring Band (Singapore), Australian Economic Papers, 41 (4), December

Rajan, Ramkishen, Rahul Sen and Reza Siregar, (2002) Misalignment of the Baht, Trade Imbalances and the Crisis in Thailand, University of Adelaide, Australia, Working Paper

Stein, Jerome L. and Giovanna Paladino (2001) *Country Default Risk: An Empirical Assessment*, Australian Economic Papers, 40, (2), December

Stein, Jerome L, Polly R. Allen et al, (1994, 1997) Fundamental Determinants of Exchange Rates, Oxford University Press

Stein, Jerome L. (2002) The Equilibrium Real Exchange Rate of the Euro: An Evaluation of Research, ifo Studien, 3/2002

Stein, Jerome L. and Guay C. Lim (2002) Introduction to Exchange Rates in Europe and Australasia: Fundamental Determinants, Adjustments and Policy Implications, Australian Economic Papers, 41 (4), December

Stein, Jerome L.(2004) *Stochastic Optimal Control Modeling of Debt Crises*, American Mathematical Society, Contemporary Mathematics

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