A joint Initiative of Ludwig-Maximilians-Universität and Ifo Institute for Economic Research

Working Papers

COUNTRY DEFAULT RISK: AN EMPIRICAL ASSESSMENT

Jerome L. Stein
Giovanna Paladino

CESifo Working Paper No. 469

April 2001

CESifo
Center for Economic Studies & Ifo Institute for Economic Research
Poschingerstr. 5, 81679 Munich, Germany
Tel.: +49 (89) 9224-1410
Fax: +49 (89) 9224-1409
e-mail: office@CESifo.de

CESifo *Working Paper No. 469*
April 2001

COUNTRY DEFAULT RISK: AN EMPIRICAL ASSESSMENT

Abstract

We provide benchmarks to evaluate what is an optimal foreign debt and a maximal foreign debt (*debt-max*), when risk is explicitly considered. When the actual debt exceeds *debt-max*, then the economy will default when a "bad shock" occurs. This paper is an application of the stochastic optimal controls models of Fleming and Stein (2001), which gives empirical content to the question of how one should measure "vulnerability" to shocks, when there is uncertainty concerning the productivity of capital. We consider two sets of high- risk countries during the period 1978-99: a subset of 21 countries that defaulted on the debt, and another set of 13 countries that did not default. Default is a situation where the firms or government of a country reschedule the interest/principal payments on the external debt. We thereby explain how our analysis can anticipate default risk, and add another dimension to the literature of early warning signals of default/credit risk.

JEL Classification: C61, F34.

Keywords: Default risk, foreign debt, stochastic optimal control, debt rescheduling, uncertainty.

Jerome L. Stein
Division of Applied Mathematics
Box F
Brown University
Providence RI 02912
USA
Jerome_Stein@Brown.edu

Giovanna Paladino
San Paolo IMI
Economic Research Department
25 viale dell'Arte
00144 Roma
Italy
Giovanna.paladino@sanpaoloimi.com

COUNTRY DEFAULT RISK: AN EMPIRICAL ASSESSMENT

Jerome L. Stein and Giovanna Paladino

I. IS THE FOREIGN DEBT A RESULT OF A BUBBLE?

Data on the credit rating of bonds issued in the first half of the 1990s suggest that investors in emerging market securities paid little attention to credit risk, or that they were comfortable with the high level of credit risk that they were incurring[1]. The compression of the interest rate yield spread prior to[2] and the subsequent turmoil in emerging markets have raised doubts about the ability of investors to appropriately assess and price risk. Moody's indicated that there was a need for a "paradigm shift" that involves a greater analytic emphasis on the risks associated with the reliance on short-term debt for otherwise creditworthy borrowers.

There is a general agreement about the qualitative or broad aspects of the Asian crises of 1997[3]. In 1990 the International Monetary Fund commended Thailand's strategy for growth. Trade and finance were liberalized, and there was a relatively restrictive fiscal policy. The liberalization stimulated investment, and the excess of investment over private saving was financed through capital inflows. There was little inflation. After the crises of 1997, the common view was that the Asian economies were in a bubble and were"vulnerable" to shocks.

The description of the bubble and "vulnerability" implied that the private external debt was "excessive". The bubble was characterized by "overinvestment" in real capital, because there were implicit government guarantees. The main guarantee was that there was a pegged exchange rate, so that the exchange risk was ignored. This led to an

[1] This section relies on International Monetary Fund, International Capital Markets, Washington DC (1999), and International Monetary Fund, Anticipating Balance of Payments Crises, Occasional Paper #186, (1999).
[2] The market expectations as embodied in interest rates did not widen significantly prior to the Mexican crisis. In the Asian crises, spreads hardly increased in the months prior to the floatation of the Bhat. The credit rating agencies and the market analysts all failed to signal the Asian crises in advance. They downgraded these countries only after the crises.
[3] See Alba et al. (1999) and Corbett and Vines (1999), Corsetti, Pesenti and Roubini(1999).

"unduly" large private external debt. There were also implicit "bailout" provisions that encouraged bank lending.

A bubble is an unsustainable phenomenon, which is burst by shocks that have positive probability. The latter results from (i) a decline in the productivity of capital, for example as a result of declines in export prices, (ii) a loss of competitiveness due to an overvalued real exchange rate, or (iii) rises in the world interest rate. It then becomes more difficult to service the external debt. When the market perceives that there will be problem servicing the debt, there will be a capital flight which drains reserves. Since banks are highly levered, the resulting depreciation of the currency leads to bank failures and rises in interest rates. A destabilizing feedback occurs where a decline in the productivity of capital interacts with rises in interest rates to generate the currency and banking crises.

A difficulty with the consensus description is that there is no benchmark for measuring "vulnerability" or "excessive" external debt. Corbett and Vines, who present this "consensus" view, nevertheless write that: vulnerability is an idea that is surprisingly difficult to pin down. One needs a "benchmark" of what is an optimal foreign debt in a world of uncertainty.

There is an extensive theoretical literature that purports to describe the evolution of the foreign debt, investment and consumption as an intertermporal optimization process by a "representative agent". The foreign debt just results from consumption smoothing. These models fail to explain exchange rate developments, currency, banking or debt crises[4]. This literature ignores risk, by making assumptions that imply *certainty equivalence,* and there is no constraint that the country repays the debt. Our paper develops a paradigm for risk management or inter-temporal optimization under uncertainty, in a finite horizon discrete time context[5] with the *constraint* that there be no default on foreign currency denominated debt. The finite time horizon model concerns

[4] For a critique of this literature see Stein and Paladino (1997). Similarly, the use of the Maximum Principle in continuous time assumes perfect certainty. Neither approach is useful in a world of risk and uncertainty. By contrast, Infante and Stein (1973) used dynamic programming to solve for inter-temporal optimization in an environment where there is not perfect knowledge. The derived suboptimal feedback control drives the economy to the unknown perfect certainty optimal path.

[5] An infinite horizon continuous time context is provided in Fleming and Stein (1999)

short-term external debt. The *constraint* in a repeating cycle of two period models is that, regardless of the state of nature in the second period, there will be no default on the debt.

We derive: (a) benchmarks for *optimal* foreign debt, which will not be defaulted in the event of adverse shocks, and (b) a quantitative measure of the *maximum* debt that satisfies the no-default constraint. Insofar as the actual debt exceeds the benchmark, the risk of default is increased. An excessive debt occurs for several reasons. (a) The agents use certainty equivalence, as is done in the theoretical literature. (b) There is the moral hazard issue, which has been stressed in the literature on crises cited above. The government provides implicit insurance, such as a pegged exchange rate, that induces firms to ignore/underemphasize risk. When the shocks occur however, the government cannot fulfill its promise. (c) The borrower is overly optimistic about the distribution function of the return to investment. (d) Both borrowers and lenders neglect to constrain the optimization that there be no default/rescheduling.

1.1 Organization

In part 2 we outline alternative theoretical approaches to evaluate *quantitatively* whether the foreign debt is either sustainable or optimal. Part 2.1 summarizes the conventional solvency/sustainability criteria. Parts 2.2 - 2.3 summarize the stochastic optimal control model of Fleming and Stein (2001). They provide benchmarks to measure "vulnerability" to shocks based on the notion of "optimal" investment, saving and short-term foreign debt, when there is uncertainty concerning the productivity of capital.

In part 3, the research design, data and sample are discussed. We consider a set of 21 countries during the period 1978-99 which "defaulted" on the debt, and a "control" group of 13 countries that did not default. *Default* is defined as a situation where private firms or the government of a country *reschedule* the interest/principal payments on the external debt owed to either commercial banks or to official institutions. On the basis of the theoretical presentation in parts 2.2 - 2.3 and research design in part 3, we compare the external liabilities of private or public debtors in countries that defaulted/did not default on their bonds with our concepts of the optimal or maximal debt/GDP. In part 3.1, we compare two countries in the two groups: Mexico and Tunisia. Parts 3.2 and 3.3

concern a comparison of the two groups based upon panel data, and state our main conclusions.

II. THEORETICAL APPROACHES TO EVALUATING EXTERNAL DEBT

2.1 The Solvency/Sustainability Criterion[6]

The literature has used a “solvency-sustainability” approach to monitor foreign debt. An economy is considered solvent if the ratio of external liabilities/GDP will remain bounded, and the debt service payments/GDP will not explode. The sustainability of the current account deficit relies on projecting into the future the current policy stance of the government and/or of the private sector. Sustainability is ensured if the resulting path of the foreign debt is consistent with “inter-temporal solvency”. We explain why the solvency-sustainability approach is not capable of revealing vulnerability.

Denote by $h(t) = L(t)/Y(t)$ the ratio of the foreign debt $L(t)$ denominated in foreign currency \$US to $Y(t)$, the real GDP also measured in \$US. The rate of change of the foreign debt/GDP is equation (1). The interest rate at which the dollars are borrowed is $r(t)$, the growth rate of the real GDP is $g(t)$, and $m(t)$ is the trade deficit/GDP. The trade defcit/GDP is equal to $j(t)$ = investment/GDP less $s(t)$ =saving/GDP. The growth rate $g(t) = (\mathrm{d}Y(t)/\mathrm{d}t)/Y(t)$ is equal to the productivity of capital $b(t) = \mathrm{d}Y(t)/\mathrm{d}K(t)$ times $j(t) = (\mathrm{d}K(t)/\mathrm{d}t)/Y(t)$ the ratio of investment/GDP. The equation for the growth of the debt is (1), *where:* $a(t) = r(t) - g(t)$ = the interest rate less the growth rate ; $m(t) = [j(t) - s(t)]$ = trade defcit/GDP; $g(t) = b(t)j(t)$ = growth rate of GDP.

$$\mathrm{d}h(t)/\mathrm{d}t = [r(t) - g(t)]h(t) + m(t) = a(t)h(t) + m(t), \qquad (1)$$

Solve for $h(t)$ the debt/GDP at any time and derive equation (2), where term $A(t) = \int a(v)\mathrm{d}v = \int [r(v) - b(v)j(v)]\mathrm{d}v$, $t > v > 0$. Think of $A(t)/t$ as the <u>average</u> interest rate less the growth rate over the interval $(0,t)$; and $A(v)/v$ as the <u>average</u> interest rate less the growth rate over the interval $(0,v<t)$.

[6] See for example International Monetary Fund, WEO May 1998, Box 8, pp. 86-87.

$$h(t) = h(0)e^{A(t)} + \int e^{(A(t) - A(v))} m(v)dv, \quad t > v > 0. \qquad (2)$$

The debt/GDP can be attributable statistically to the components of (2): sustained trade deficits, m(t) > 0 equal to sustained excess of investment minus saving, interest rates in excess of growth rate *a*(t) > 0, and low growth rates b(t)j(t) due to either low productivity of capital or low investment ratios.

The solvency-sustainability literature looks at the "debt burden" as a measure of "vulnerability". The "debt burden" *DB(T*) is defined in equation (2.1) as the trade surplus [-m(T)] required to keep the ratio of the debt/GDP ratio constant at its <u>current</u> level at time T, denoted *h(T)*. The solvency/sustainability argument assumes that current [*r(T) - g(T)*] is given. Then the higher is *DB(T)*, the more burdensome is the debt, and the greater the likelihood of default.

$$DB(T) = [r(T) - g(T)]h(T) \qquad (2.1)$$

This approach does not allow one to evaluate whether a debt is excessive and whether it will lead to vulnerability, for the following reasons. First: it is impossible to know the future value of the debt *h(t)* for *t > T,* because the future growth rates and interest rates are unknown. This means that quantities *A(t)* and *A(v)* in equation (2) are unknown. Second: the trade deficit *m(t)* and the growth rate *g(t)* are not independent. A trade deficit that finances investment *j(t)* will lead to a higher growth rate in the future, since the growth rate is the product of the productivity of capital and the investment rate. Third: a trade deficit in the present does not imply a high debt in the future. For example, a high rate of return on investment relative to the world interest rate stimulates capital formation. The latter raises investment less saving, generates a capital inflow, which appreciates the real exchange rate. The latter leads to a trade deficit, which accomplishes the transfer of resources, and the debt rises. The higher investment ratio times the productivity of capital will eventually raise the growth rate. In other words, the higher productivity of capital will eventually raise GDP and saving, and generate a trade balance to repay the debt. The debt may go through a cycle: it first may rise and then decline below its initial level. Consequently, it is misleading to look the debt burden *DB*(T) = [*r(*T*) - g(*T)]*h(T)* based upon the <u>current</u> values, and infer whether or not there will be a debt crisis. Nor is it useful to look at the <u>current</u> trade deficit [*j(T) - s(T)*] to infer vulnerability. It is no surprise that the researchers who have used the solvency-sustainability approach have doubted its usefulness. The International Monetary Fund WEO Report (May 1998, Box 1, p. 87) wrote: "…these simple solvency tests would clearly have failed to signal problems ahead for the fast-growing Asian economies, including Indonesia and Korea".

2.2 Stochastic Optimal Control

Fleming and Stein [F-S:1999, F-S:2001] derived the optimal levels of the foreign debt L(t), investment J(t) and consumption C(t) in a world of uncertainty, subject to the constraint that there be no default/rescheduling. [F-S:1999] analyze optimization over an infinite horizon in continuous time, using the techniques of stochastic optimal control-dynamic programming. [F-S:2001], focus on a repeating two period model where the debt is short-term. Risk is explicitly considered: there is no certainty equivalence, as is assumed in the literature. The "no default" constraint in the optimization is crucial. The derivations in both the models are extremely technical. We therefore just present an intuitive discussion of the discrete time case, which leads into the empirical analysis.

2.3 Stochastic Optimal Control: Discrete Time over a Two Period Horizon

We consider a series of repeating two period cycles. In the first period, the GDP denoted by $Y(1) = b(1)K(1)$, where $K(1)$ is the capital stock and $b(1)$ is the current productivity of capital. In period $t = 1$, the country selects consumption and investment. The trade deficit, equal to consumption plus investment less the GDP, is financed through short-term foreign debt. The interest rate r is known. The productivity of capital b(2) in period $t = 2$ is the crucial stochastic variable. The GDP in the second period is $Y(2) = b(2)[K(1) + J(1)]$, where $K(1)$ is the initial capital and $J(1)$ is the rate of investment in the first period. The variables are measured in $US.

The productivity of investment $b(2)$ is stochastic for the following reason. Dollars are borrowed at interest rate r to purchase capital and produce an output, which is sold in the world market. The dollar value of the output depends upon several factors: the terms of trade (export/import prices), the exchange rate of the country and the productivity of the investment. If the terms of trade deteriorate, the investment is ill advised or the exchange rate depreciates, the productivity of the investment $b(2)$ measured in $US declines. Then the repayment of the dollar denominated debt is more costly. Instead of viewing the effect of exchange rate uncertainty upon the interest payments denominated in foreign currency, we view the uncertainty via the productivity of investment.

The risk/uncertainty is contained in the net return on investment $x = [b(2) - r]$, the stochastic productivity of capital $b(2)$ less r, the known interest rate. The range of $b(2)$ is $r \pm a/2$, $a > 0$. The values of the net return $x = [b(2) - r]$ are symmetrical around zero with a range $a > 0$, as described in Box 1, with probabilities (p, $1-p$), $1 > p > 0$, in the good and bad case respectively. This is a simple and general formulation that makes minimal assumptions about the distribution function.

BOX 1. UNCERTAINTY CONCERNING THE NET RETURN x = [b(2) - r]

<u>b(2)</u>	<u>Pr(b)</u>		Consumption C(2)
$b^+(2) = r + a/2$	$1 > p > 0$	good case	$C^+(2)$
$b^-(2) = r - a/2$	$(1-p) > 0$	bad case	$C^-(2)$

Productivity of capital in the second period is $b(2) = Y(2)/K(2)$. The interest rate is r. The net return is $x = b(2) - r$. The expected net return $E(x) = E[b(2)-r] = a(p - 1/2)$; range $[b(2)-r] = a > 0$. Risk concerns the realization of the "bad" case. $Var(x) = a^2p(1-p)$

The optimization concerns the sum of the utility of consumption in the first period plus the expectation of utility of consumption in the second period. The consumption in the second period is equation (3). It is equal to the <u>stochastic</u> GDP less the repayment of debt and interest $(1+r)L(2)$ less investment $I(2)$. <u>Default/rescheduling of debt</u> will occur if consumption in period two falls below a certain minimum tolerable level, which we shall call $C(t)_{min} = 0$. The "no default" constraint is that $C(2)$ in equation (3) be positive.

$$C(2) = b(2)[K(1) + J(1)] - (1+r)L(2) - I(2) > 0. \tag{3}$$

The debt carried into the second period $L(2)$ is consumption plus investment less GDP in the first period, the trade deficit, equation (4)

$$L(2) = C(1) + J(1) - b(1)K(1). \tag{4}$$

In a series of repeating cycles, we use a terminal condition that the capital at the beginning of period t = 3 is the same as the initial capital K(1). This implies condition (5).

$$J(1) + J(2) = 0. \tag{5}$$

Then the consumption in the second period is equation (6), using (3)(4) and (5). The no-default constraint is that C(2) > 0.

$$C(2) = b(2)K(1) + [b(2) - r]J(1) + (1+r)[b(1)K(1) - C(1)] > 0 \qquad (6)$$

The net return on investment $[b(2) - r]$ is $a/2$ in the good case with probability p, and $(-a/2)$ in the bad case with probability $(1-p)$. The consumption in the good case is $C^{+}(2)$, and is $C^{-}(2)$ in the bad case.

The utility is a HARA function $U(C(t)) = (1/\gamma)C(t)^{\gamma}$, where $\gamma < 1$. Risk aversion is $(1-\gamma) > 0$. The most interesting and useful cases are when $\gamma \leq 0$. The $\gamma = 0$ case is the logarithmic utility function. Then the utility of zero consumption is minus infinity; and the optimization will avoid that situation. Controls $C(1)$ and $J(1)$ are selected in period t=1 to maximize the sum of the expected utility of consumption over the two periods, subject to the no-default constraint. This is equation (7), using (6).

$$\max E[J] = \max \{(1/\gamma)C(1)^{\gamma} + (1/\gamma)[pC^{+}(2)^{\gamma} + (1-p)C^{-}(2)^{\gamma}] \} \qquad (7)$$

[F-S:2001] then derive the optimal consumption, saving and investment in the first period, and resulting debt. An asterisk denotes constrained optimal values. The *constrained optimization (C-O)* explicitly considers risk, since there is no assumption of certainty equivalence.

2.3.1 The Maximal Debt: No default constraint

The maximal debt is defined as the debt associated with zero consumption, if the bad case materializes. Hence if the actual debt exceeds <u>the maximal debt</u>, this is a sufficient condition that there will be default/renegotiation. The no default constraint is described as follows. Divide equation (6) by initial output Y(1) = b(1)K(1), where c(1) = C(1)/Y(1), c(2) = C(2)/Y(1), j(1) = J(1)/Y(1) and f(2) = L(2)/Y(1). We obtain equation (8).

$$c(2) = b(2)/b(1) + [b(2) - r]j(1) + (1+r)[1 - c(1)] > 0 \qquad (8)$$

Consumption c(2) will be zero in the bad case where $b^{-}(2) = r - a/2$ if equation (9), graphed in figure 1, is satisfied. The higher the investment rate j(1), which has a negative net return $(b^{-}(2) - r) = -a/2 < 0$, the lower must be initial consumption c(1) to ensure that c(2) = C(2)/Y(1) > 0.

$$c(1) = \{[(b^{-}(2)/b(1)] /(1+r) + 1\} + [(b^{-}(2) - r)/(1+r)]\, j(1) => c(2) = 0 \qquad (9)$$

Equation (9) is the hypotenuse of right triangle 0AB in figure 1. Call the interior of 0AB the *no default constraint.* For values of {c(1), j(1)} outside the triangle, c(2) will be negative.

Figure 1. Consumption c(1) and investment j(1), per unit of Y(1). No default constraint c(2) > 0 is that [c(1), j(1)] lie inside triangle 0AB.

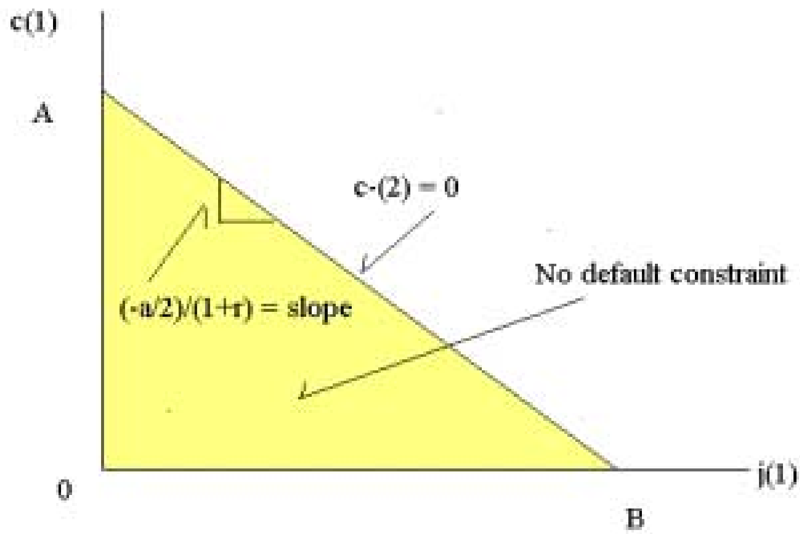


Figure 1. No default constraint c(2) > 0

The debt L(2)/Y(1) = f(2) = c(1) + j(1) - 1. Substitute c(1) = f(2) + 1 - j(1) in equation (9) to obtain the maximal debt, denoted (f-max). Equation (10) is a transformation of equation (9) in terms of debt f(2) and investment j(1). If the actual debt exceeds the maximal then the economy is above triangle 0AB, and with probability ($1-p$) > 0 there will be a default.

$$f\text{-max} = [b^{-}(2)/b(1) + (1 + b^{-}(2))\, j(1)] / (1 + r). \qquad (10)$$

2.3.2 Optimization

The C-O debt, investment and saving are described in figure 2 based upon equations (10)-(12). All are measured as fractions of current GDP, which is $Y(1) = b(1)K(1)$. The expected net return denoted by E(x) = E[$b(2) - r$] = $a(p - 1/2)$, is plotted on the abscissa. Here, we only present the results where the utility of consumption is logarithmic[7].Optimal saving/GDP in period one s*(1) is independent of the expected net return[8], equation (11).

$S(1)/Y(1) = s^{*}(1)$, independent of E(x) . (11)

In the standard literature, which makes the certainty equivalence (CE) assumptions, the optimal stock of capital is adjusted until the expected marginal productivity is equal to the interest rate. If the expected productivity of capital is independent of the stock of capital, there will be a "bang-bang" solution. If E(x) = E[$b(2) - r$] > 0, a maximal/infinite amount will be borrowed at rate r to finance the maximal investment. A maximal amount of risk is assumed. If E(x) < 0, then investment is zero, and the country is a creditor equal to saving s*(1). The CE debt is CE-0-CE' in figure 2, where 0C' practically coincides with the ordinate.

In our model where risk is explicitly taken into account and there is a no-default/rescheduling constraint, we obtain a very different result. Even though there are no diminishing returns to capital, the investment ratio $j(1)$ in equation (12) does not have a bang-bang solution. Optimal investment $j^{*}(1)$ is zero, for values of the expected net

[7] The general case is shown in tables 2 and 3 in Fleming-Stein (2001).

return E(*x*) = E[*b(2) - r*] less than *d*, where $d = (a/2)^2/A > 0$. The numerator is the square of downside risk $(a/2)^2$, and coefficient $A = [(1+b(1))(1+r) - 1] > 0$. For values of E(*x*) > *d*, the investment rises in proportion to coefficient *A* > 0. Unlike the certainty equivalent case in the literature, the (C-O) rate of investment is zero, even if the expected productivity of capital exceeds the interest rate, but by less than d>0.

<u>When $E(x) > d = (a/2)^2/[(1+b(1))(1+r) - 1] > 0$:</u>

$$I(1)/Y(1) = j^*(1) = A(E(x) - d), \qquad (12a)$$

<u>When E(*x*) < *d*:.</u>

$$j^*(1) = 0 \qquad (12b)$$

The C-O debt/GDP carried into period two, $f^*(2) = L(2)/Y(1) = j^*(1) - s^*(1)$ is the doubly bent line CE-A-e-B-C in figure 2, equal to the vertical difference between investment, equation (12) less the constant saving ratio *s*(1)*. Equation (13) and figure 2 describe the C-O foreign debt f*(2) carried into period two, per unit of GDP in period one, where *s*(1)* and *j*(1)* are given by the equations above. Section BC of the curve in figure 2 embodies the no default constraint (f-max).

$$(13)\ f\text{-}max > f^*(2) = j^*(1) - s^*(1).$$

Figure 2. Constrained optimal (CO) debt f*(2) as fraction of GDPin a repeating 2-period model. x = b(2) - r. When E(x) < d, the country is a creditor/GDP equal to s*. The debt/Y(1) is zero at E(x) = e and rises linearly to a maximum of f-max. The certainty equivalent (CE) debt is CE. The creditor position is saving s* for E(x) < 0; and for E(x) > 0, the debt/GDP is infinite.

[8] This is the logarithmic case.

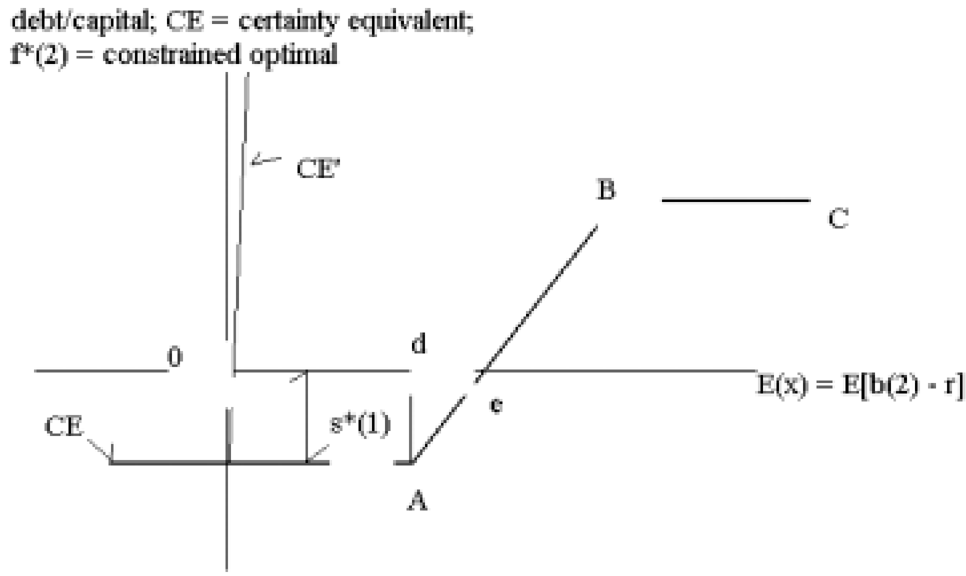


Figure 2. Constrained optimal f*(2) is CE-A-B-C; certainty equivalent is CE-CE(ordinate)

In figure 2, the country should be a net creditor if the expected net return on investment E(x) = $a(p - 1/2)$ is less than e It should be a debtor when E(x) exceeds e. The maximum debt/GDP is f-max. With the derived C-O debt and investment, the present value of expected utility is maximal, subject to the constraint that there will be no default if the "bad event" occurs: $x = (-a/2) < 0$. As the actual debt exceeds the C-O debt $f^*(2)$, the present value of expected utility declines, and the probability of default increases.

One *benchmark* for evaluating the actual debt/GDP is that it should be the constrained optimal debt $f^*(2) = j^*(1) - s^*(1)$, curve CE-A-e-B-C in figure 2. A weaker benchmark for the debt is that there should be no default: $f(2) < f$-max.

III. RESEARCH DESIGN: SAMPLE, DATA AND TESTABLE HYPOTHESIS

The [F-S:2001] stochastic optimal control model relates the constrained optimal total external public plus private debt of a country to fundamental variables. In our empirical work, we consider a set of 21 countries that concluded rescheduling agreements on their external private[9] plus public debt with commercial banks and with official creditors during the period January 1980 - December 1999. Appendix 1 and table A2, derived from the World Bank "Global Development Finance", list the entire set of countries that rescheduled and the dates of agreement. These countries are contrasted with thirteen emerging market countries that did not default, table A3.

The basic variables are[10]: the actual external public debt/GDP ratio $h(t)$, the productivity of capital $b(t)$, the interest rate $r(t)$ on foreign currency denominated debt, the growth rate $g(t)$ of real GDP, and the ratio $j(t)$ of investment/GDP. An estimate of the gross productivity of capital $b(t)$ is the inverse ICOR[11], where $b(t) = dY(t)/dK(t) = [dY(t)/dt / Y(t)] / [J(t)/Y(t)] = g(t)/j(t)$, equal to the growth rate of GDP divided by the ratio

[9] In some cases, private borrowing was supported by implicit government guarantees.
[10] Our data are from: World Bank (Global Development Finance), the IMF(International Financial Statistics) and IIF(countries data sets).
[11] ICOR is the incremental capital output ratio.

of gross investment/GDP. The net return *x(t) = b(t) - r(t)*. The productivity of investment *b(t)* is gross of depreciation and obsolescence.

The debt/GDP ratio combines short and long term external debt, but the theoretical analysis is based upon a two period model where the debt plus interest must be repaid. A similar relation between the optimal debt/GDP and the net return is found in both the infinite horizon model and in the two period model. The difference is that in the two period model, the debt plus interest must be repaid by the end of period two; and in the infinite horizon model, the only requirement is that the debt must always be serviced. Operationally, the only significant difference is in the concept of the maximal debt f-max. Given the mix of maturities, we use the inclusive measure of the external debt.

The application of the Fleming-Stein theoretical analysis is carried out in two parts. First: we compare Mexico, a country that defaulted/rescheduled his debt, with Tunisia which did not default. Second: we examine the panel data of the countries that defaulted relative to those that did not.

3.1. Comparison between Mexico and Tunisia

Mexico experienced currency crises in September 1976, February and December 1982 and December 1994, and concluded ten debt- rescheduling agreements with commercial banks, and three with official creditors, during the two decades January 1980 - December 1999 (see appendix 1). These agreements were concentrated in the periods 1983-90 and 1996. Tunisia is not listed among the countries that rescheduled. A comparison of the two countries provides us a better understanding of the subsequent panel data analysis. Table 1 summarizes the basic relations used in our analysis.

Table 1. COMPARISON OF MEXICO AND TUNISIA

The median debt/GDP, row 1, was higher in Tunisia (0.61), which did not default than in Mexico (0.45), which rescheduled many times in our sample period 1980-99. It is not the debt ratio h(t) that determines the probability of default, but rather an excess of the actual ratio h(t) compared to the debt-max.

Equation (10), repeated here, is the relation between the debt and j(1) which will lead to a zero consumption in the bad case, when $b(2) = b^{-}(2)$. This corresponds to the situation in figure 1. When c(1) is on or above the triangle 0AB, then default will occur in the bad case. The f-max corresponds to the hypotenuse line AB, as described in section 2.3.1 above. The value of f-max in (10) is conditional upon the rate of investment j(1*)*. We see in table 1, row 5, that there was a small variance to the rate of investment/GDP in the countries. We use the median rate of investment as j(1). The interest rate is in row 4.

Box 1 above presents our theoretical concept of the distribution of the gross return b(2) in the good and bad cases. Figures 3 and 4 are histograms of the gross return *b(t)* denoted B1 in Mexico which defaulted/rescheduled and Tunisia which did not, respectively. It is essential to study these histograms to estimate *b(2)* in the good and bad cases.

In the Mexican case, the left tail of the gross return *b(t)* figure 3, reflects the debt crises periods 1994-95, where the return fell drastically as a consequence of the crisis. We minimize the weight of these outliers in the distribution of *b (t)* the gross return, by taking as our measure of the expected return E[*b(2)*] = 0.15 in row 2 to be the median gross return. We assume that b(1) was equal to the expected return The distribution of *b(t)* is stationary/mean-reverting. The standard deviation of the gross return 0.16 is taken to be an estimate of (*a/2*). Therefore the bad case $b^{-}(2) = .15 - .16 = -0.01$, in row 3. The investment ratio *j(1)* is the median investment/GDP ratio 0.22, in row 5; and the interest rate *r* is taken as the median 0.08 in row 4.

The f-max for Mexico, based upon (10) is (10-MEX) equal to the maximal debt/GDP that Mexico can have and yet repay if the bad event occurs. It is based upon the histogram in figure 3 and data in table 1. Row 8, column 1 in table 1, states that f-max for Mexico is 0.13. A similar calculation for Tunisia implies that f-max is 0.73: row 8, column 2, in table 1 above.

$$f\text{-max} = [(b^{-}(2)/b(1)) + (1 + b^{-}(2))j(1)] / (1 + r) \qquad (10)$$

$$f\text{-}max = [(-0.12)/(.15) + (1 - .012)(.22)] / (1.08) = .13 \qquad \text{(10-MEX)}$$

It is not the debt ratio h(t) that is relevant for default (DEF), but the excess of the actual debt over f-max. We calculate the difference (DEF) between the actual median debt and f-max. If DEF > 0, then the debt is “excessive” and the country is likely to default in the event that the bad case occurs. The resulting values of DEF = [actual median debt/GDP - (f-max)] is in the row 9 of table 1. In Mexico, DEF = .45 - .13 = .32 and in Tunisia, DEF = -.116. Since the Mexican debt exceeded f-max, then default would occur if the bad event arose.

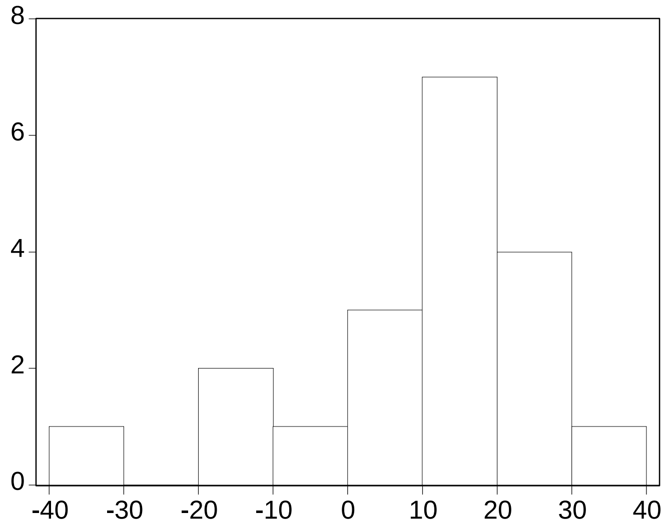
Figure 5 is even more revealing. We plot the annual DEF(t) = h(t) - (f-max) = actual debt/GDP in each year less the f-max (row 9 in table 1), for Mexico and Tunisia. In Mexico, there was an excess debt DEF > 0 in every year 1978-99. In Tunisia, the excess debt DEF < 0, except for a short period when it was slightly positive. The conclusions are Mexico would default/reschedule, whereas Tunisia could repay the debt.

Figure 3. Mexico. Histogram of gross return b(t) = growth/investment ratio

Figure 4. Tunisia. Histogram of gross return b(t) =growth/investment ratio

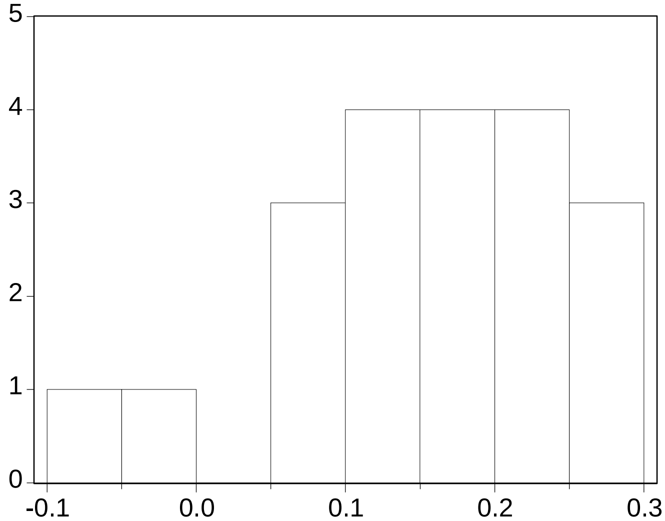
Figure 5: Excess debt = DEF = debt/GDP - $(debt/GDP)_{max}$, in Mexico and Tunisia

Figure 3
Mexico Histogram of rate of return B1 = b(t)
= growth rate/investment ratio



Series: B1_MEX
Sample 1981 1999
Observations 19

Mean	10.19493
Median	15.12098
Maximum	30.97354
Minimum	-31.11466
Std. Dev.	16.27297
Skewness	-1.193285
Kurtosis	3.450504
Jarque-Bera	4.669781
Probability	0.096821



Series: B1_TU
Sample 1979 1998
Observations 20

Mean	0.153383
Median	0.166540
Maximum	0.271218
Minimum	-0.081165
Std. Dev.	0.093626
Skewness	-0.833685
Kurtosis	3.102572
Jarque-Bera	2.325536
Probability	0.312620

Figure 4.

Tunisia. Histogram of rate of return B1 = b(t).

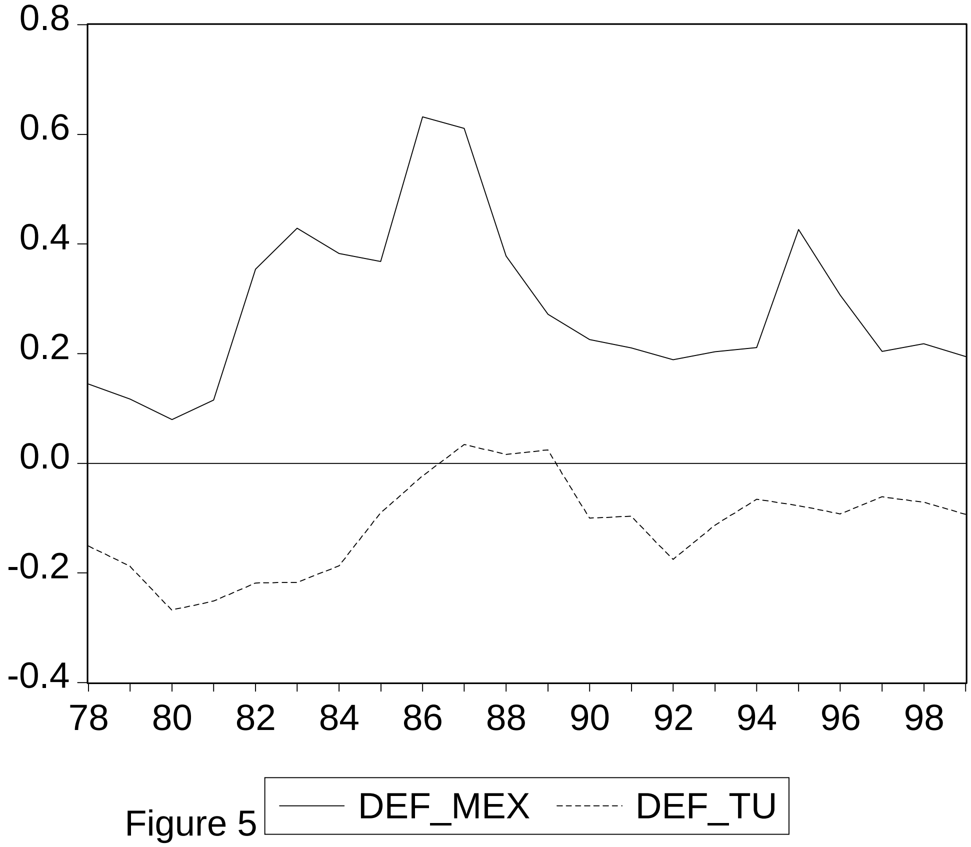


Figure 5
MEXico, TUnisia
Excess debt/GDP, DEF(t) = (debt/GDP)(t) - (f-max),

Table I
COMPARISON OF MEXICO AND TUNISIA

Variable: median, [range], (σ)	**MEXICO**	ADF	**TUNISIA**	ADF
1.Debt/gdp = *h(t)*	.45 [.81, .29](.14)	-2.5	.61 [.74, .44](.09)	-1.8
2.Gross return = *b(t)*	.15 [.30, -.31](.16)	-3.3*	.167[.27,-.08] (.09)	-3.5*
3. bad case $b^{-}(2)$	(median b(2)- 1σ) = -.012		(median b(2)-1σ) = .077	
4.Interest rate= *r(t)*	.08 [.15, .07] (.02)	-1.89	.05[.06,.04] (.004)	-3.67*
5.Investment/gdp = *j(t)*	.22 (.02)	-1.55	.28 (.04)	-3.67*
6.Net return= *x(t)*	.057[.17,- .39](.16)	-2.1	.107 [.21,-.13](.09)	-3.47*
7.Growth = *g(t)*	.035[.08,-.06] (.036)	-3.07*	.049[.086, -.02] (.028)	-3.5*
8.f-max	.13		.73	
9.DEF = *h(t)* - *f*-max	.322		-.116	
10.Cor(*h*,*x*)	-.67		-.24	
11.Cor(*b*,*r*)	.02		-.11	

Actual debt/GDP = *h(t)*; maximal debt/GDP = *f*-max. We use median *b(1), j(1), r(1)* to eliminate the outlier which may have been the consequence of the currency crisis. ADF is significant if there is an asterisk.
f-max = $[b^{-}(2)/b(1) + (1+b^{-}(2))\, j(1)]/(1+r)$ is evaluated at the median investment ratio j(t). The net return is: $x(t) = b(t) - r(t)$.

3.2. Panel data analysis

The theory figure 2 describes the relation between $f^*(t)$ the constrained optimal debt/GDP and the expected net return E[x(t)]. The net return x(t) = b(t) - r(t) = g(t)/j(t) - r(t), where g(t) is the growth rate and j(t) is the investment ratio. As x(t) varies around a stationary mean E[x(t)], the optimal f(t) should be constant. If one simply compared the actual net return x(t) = g(t)/j(t) - r(t) with the actual debt/GDP , there is a negative bias. When a crisis occurs, the growth rate $g(t)$ declines and the actual GDP may fall. This tends to raise h(t) = $L(t)/Y(t)$ and lower the net return x(t). A noteworthy example is Mexico (default), during the crisis 1980-82. The drastic decline in the return and the rise in the debt/GDP may have been consequences of the crisis and reactions to it. An analysis of panel data: country by sub-period may diminish the effect of the bias between debt/GDP and net return.

Appendix tables A2 and A3 contain the panel data for the two sets of countries: default/reschedule and a control group that did not default. The <u>default countries</u> are: Algeria, Argentina, Bolivia, Brazil, Chile, Ecuador, Egypt, Honduras, Indonesia, Iran, Korea, Mexico, Morocco, Peru, Philippines, Poland, Romania, Russia, South Africa, Turkey, Uruguay, Venezuela. The <u>control countries</u> are: China, Czech Republic, Estonia, Hungary, Slovenia; India, Kuwait, Lebanon, Malaysia, Saudi Arabia, Tunisia, United Arab Emirates, Zimbabwe. The growth and stability in the control set of countries are tenuous, investment there is very risky, but they have not as yet defaulted. Tables A2 and A3 contain the values of debt/GDP = $h(t)$, the return = $b(t)$, the interest rate $r(t)$, the net return $x(t) = b(t) - r(t)$, and the investment/GDP ratio = $j(t)$, during four periods: 1980-84, 1985-89, 1990-94, 1995-99. Table 2 summarizes the key relations that are pertinent to our analysis.

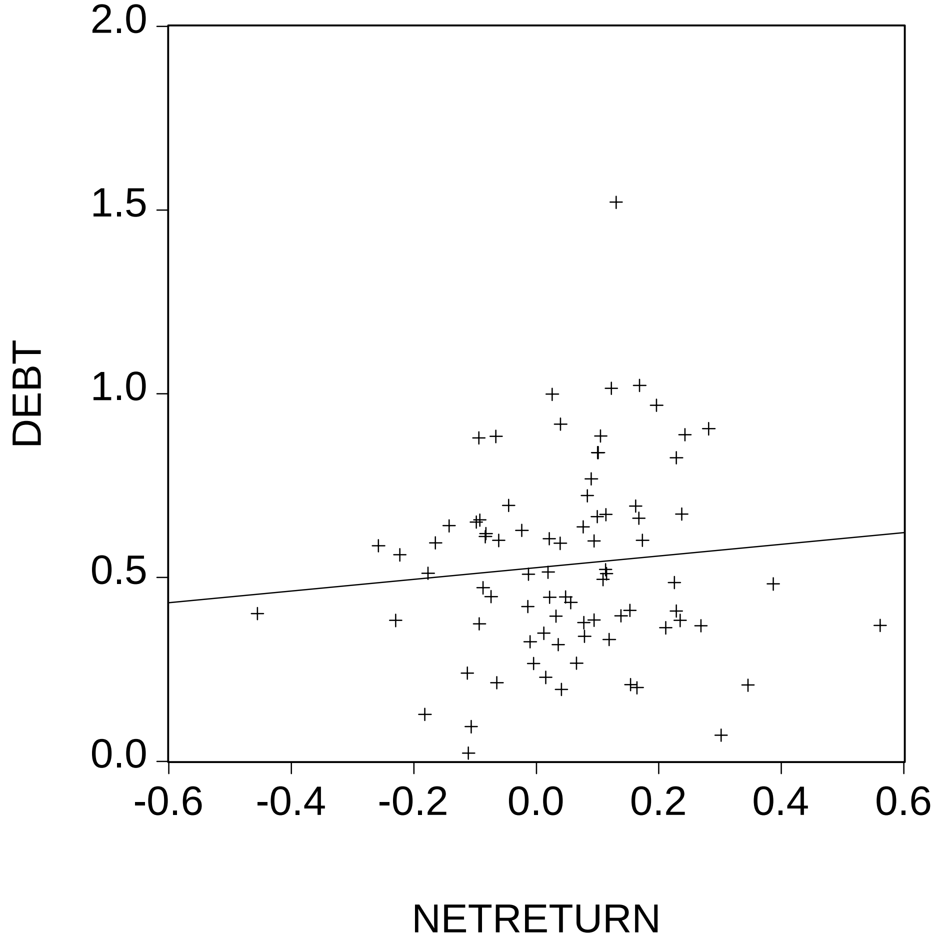
Table II

Scatter diagram figure 6 relates the h(t) = debt/GDP ratio to the x(t) = net return in a panel of default/reschedule countries. Figure 7 does the same for the countries that did not default/reschedule.

Figure 6. Scatter diagram, panel data Default countries: debt/GDP on net return

Figure 7. Scatter diagram, panel data Control countries: debt/GDP on net return

Figure 6. Default/reschedule countries
panel: 1980-84, 1985-89,1990-94,1995-99
h(t) = debt/GDP on x(t) = net return



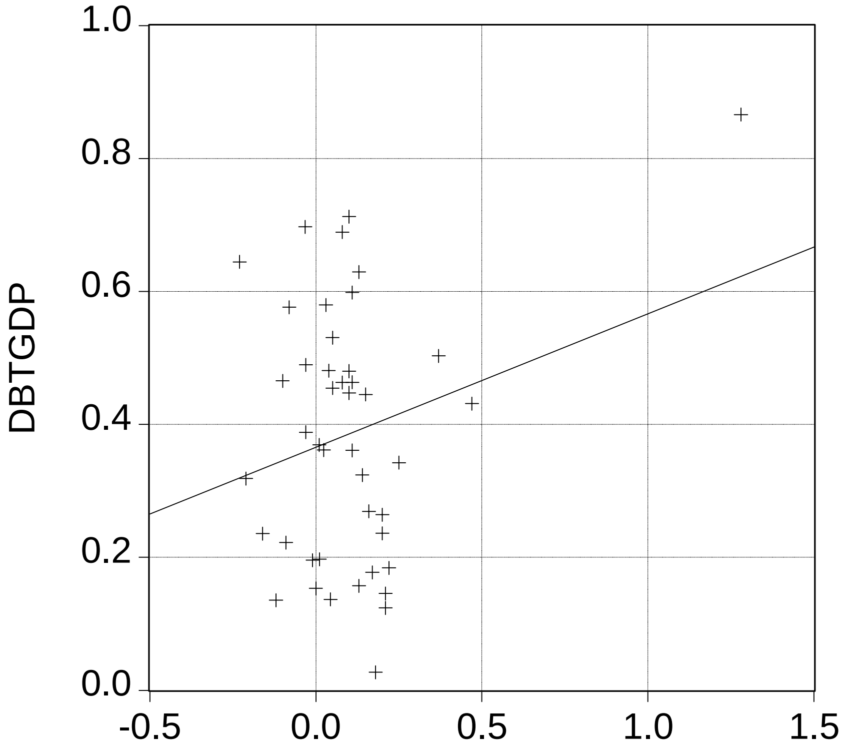


Figure 7 NETRETURN
Control group panel: 1980-84, 1985-89,1990-94,1995-99
h(t) = debt/GDP on x(t) = net return

Our *conclusions* are the following, based upon scatter diagrams figures 5,6,7 and table 2. (A) In neither set of countries was the debt-net return relation even qualitatively optimal. Both sets of countries are poor credit risks indeed. (A1) In neither set of countries is the debt/GDP ratio positively and significantly correlated with the net return (A2) Positive debt is associated with a zero net return, despite the great risk measured by the standard deviation of the return. Compare figures 6-7 with the constrained optimal case figure 2, where a positive debt is only optimal if the expected net return exceeds a quantity $d > 0$, where d is positively related to the downside risk. (B) Both sets of countries were similar except in one respect. Table 2 shows that: (B1) The median net return x was higher, but not significantly so, in the control group. (B2) The investment ratios $j(t)$ were similar. (B3) The maximal debt/GDP was similar in the two groups. The crucial difference was that: (C1) the actual debt/GDP was significantly higher in the default group. (C2) Since the value of f-max was similar, the DEF = excess debt/GDP was significantly positive 0.16 among the default countries, whereas DEF was not significantly positive among the control countries.

Table II

PANEL DATA: DEFAULT COUNTRIES VS CONTROL/NO DEFAULT COUNTRIES

periods: 1980-84, 1985-89, 1990-94, 1995-99

Variable: mean (σ)	Default	Control *
Debt/gdp, *h(t)*	.53 (.26)	.37 (.18)
f-max	.37	.34
DEF=debt/gdp - f-max	.16	.03
Return *b(t)*	.12 (.15)	.14 (.13)
Net return *x(t)*	.05 (.16)	.07 (.14)
Investment/GDP *j(t)*	.23 (.06)	.26 (.06)
Correlation [*h(t)*,*x(t)*]	.09	-0.13

*exclude Kuwait, 1990-94

3.3 Early Warning Signals (EWS) of bubbles, vulnerability to shocks and default

We can derive early warning signals that an economy is vulnerable to shocks that will lead to a default/rescheduling. Based upon the evidence in tables 1 and 2, the EWS of the rescheduling should be a DEF(default) variable that is significantly positive and persistent. To avoid false signals we require that, to be taken as an on-signal, DEF = [h(t) - (f-max)] = [debt/GDP - (debt max /GDP)] be positive and either exceed one standard deviation or that it has been rising. To examine the explanatory power of such a system we construct a 2X2 contingency table 3. Each country in each sub-period is considered one observation. The default (control) country data are in appendix table A2 (A3).

The rows of table 3 are the signal on/off. The first row refers to the on-signal. It is conditioned on (a) the sign of DEF and whether either (b1) or (b2) below is satisfied. The second row is the off- signal: the complement of the first row.

On-signal

(a) DEF= [h(t) - (f-max)] > 0, and one of the following:
(b1) DEF > 1σ or (b2) DEF rising.

The columns in table 3 refer to the occurrence/non-occurrence of rescheduling during the subperiod. Rescheduling is a legal act and comes after a period of difficulties. A caveat is that political factors are operating so that there is often a political bailout. However, if the country falls in row 1, this may be an EWS of a political bailout.

Table III, Contingency table by country

In 84% (= 43/51) of the periods of rescheduling the DEF variable has been positive and was either greater than 1 standard deviation or rising. In contingency table 3, each country has been analysed by sub-period. The rows refer to the on/off signal. The columns refer to the occurrence/non-occurence of rescheduling during the subperiod. The χ^2 test concerns the independence of the rows and columns. Since the value of $\chi^2(1)$

= 17.6 falls in the rejection region, we have to reject the null hypothesis of independence of the two classification[12].

The conclusion is that: In the event of the bad case the countries in row 1, those who have large and positive DEF, are expected to default, whereas those in row 2 where DEF $\leq$ 0 are not. Applying the Fleming/Stein mathematical analysis, we have provided quantitative measures of whether economies are vulnerable to shocks that may lead to default. These measures have been shown to have significant explanatory value.

[12] To further investigate the explicative power of the DEF= [h(t) - (f-max)] variable, we carried out a probit analysis. The results are encouraging. The DEF is significant and positive, with a marginal effect of 11%.

Table III

CONTINGENCY TABLE BY COUNTRY

Number of observation in that category (expected cell frequency);
Total Number of obs. 127

	Recheduling	*No Rescheduling*	*Total*
DEF>0; and (i)DEF >1 σ or (ii) DEF rising	43(30.8)	36(46.2)	79
DEF<0 and (i)DEF<1 σ or (ii) DEFdeclining	8(19.2)	40(28.8)	48
Totals χ^2 = 17.6 (1 d.f)**	51	76	127

Note: Each country has been analysed by sub-period, based upon appendixes 2 and 3.

Appendix 1

List of Multilateral Relief Agreement with official and private creditors January 1980-December 1999

Country	Official creditors	Private Creditors
Algeria	1994; 1995	1992;1995
Argentina	1985;1987;1989;1991;1992	1983;1985;1987;1993
Bolivia	1986;1988; 1990;1992;1995:1998	1980;1981;1988;1992;1993
Brazil	1983;1987;1988;1992	1983;1984;1986;1988;1992;1994
Chile	1985;1987	1983;1984;1985 1987;1988;1990
Ecuador	1983;1985;1988;1989;1992;1994	1983;1985;1987;1995
Egypt	1987;1991	
Indonesia	1998	1998
Iran		1993;1994
Korea		1998
Mexico	1983;1986;1989	1983;1984;1985;1987;1988;1990;1996
Morocco	1983;1985;1987;1988;1990;1992	1986;1987;1990
Peru	1983;1984;1991;1993;1996	1980;1983;1996
Philippines	1984;1987;1989;1991;1994	1986;1987;1990;1992;1996
Poland	1981,1985;1987;1990;1991	1982;1983;1984;1986;1988;1989;1994
Romania	1982;1983	1982;1983;1986;1987
Russian Federation	1993;1994;1995;1996;1999	1991;1993;1995;1998
South Africa		1985;1986;1987;1989;1993
Turkey	1980	1982
Uruguay		1983;1986;1988;1991
Venezuela		1986;1987;1988;1990

Source. World Bank , Global Development Finance 2000 Table A2.3 and Table A3.2

Appendix 2

Table A2

Summary Table Default Group

Country		1980-1984				1985-1989				1990-1994				1995-1999			
Country		b(t)	Rn(t)	j(t)	h(t)	b(t)	rn(t)	j(t)	h(t)	b(t)	rn(t)	j(t)	h(t)	b(t)	rn(t)	j(t)	h(t)
Algeria	(ALG)	0.117	0.085	0.370	0.394	0.056	0.072	0.309	0.421	-0.012	0.070	0.278	0.611	0.148	0.065	0.241	0.722
Argentina	(AR)	0.013	0.106	0.201	0.373	-0.073	0.082	0.125	0.640	0.333	0.064	0.176	0.369	0.117	0.069	0.188	0.446
Bolivia	(BOL)	-0.053	0.114	0.142	0.594	0.089	0.063	0.146	0.996	0.277	0.049	0.151	0.826	0.212	0.050	0.190	0.694
Brazil	(BR)	0.683	0.122	0.169	0.369	0.225	0.087	0.223	0.396	0.079	0.058	0.215	0.348	0.098	0.062	0.217	0.317
Chile	(CHL)	0.082	0.127	0.156	0.696	0.289	0.093	0.212	0.968	0.303	0.077	0.244	0.486	0.206	0.054	0.255	0.410
Ecuador	(ECU)	0.097	0.110	0.218	0.508	0.125	0.085	0.207	0.917	0.178	0.056	0.201	1.015	-0.034	0.059	0.185	0.879
Egypt	(EGY)	0.334	0.052	0.302	0.904	0.184	0.054	0.298	1.521	0.154	0.049	0.226	0.885	0.262	0.034	0.208	0.408
Indonesia	(INDO)	0.249	0.084	0.258	0.200	0.160	0.066	0.325	0.599	0.229	0.056	0.335	0.601	-0.008	0.057	0.248	0.883
Iran	(IR)	0.331	0.030	0.201	0.070	-0.097	0.013	0.145	0.022	0.354	0.008	0.199	0.207	0.093	0.052	0.229	0.195
Korea	(KOR)	0.213	0.099	0.304	0.510	0.307	0.072	0.311	0.383	0.203	0.049	0.371	0.208	0.125	0.046	0.320	0.341
Mexico	(MEX)	0.061	0.135	0.226	0.448	0.062	0.086	0.205	0.628	0.174	0.079	0.220	0.384	0.101	0.079	0.237	0.446
Morocco	(MOR)	0.152	0.050	0.253	0.840	0.214	0.045	0.231	1.02	0.146	0.056	0.228	0.768	0.097	0.058	0.212	0.592
Peru	(PER)	0.012	0.098	0.282	0.472	0.010	0.072	0.281	0.601	0.157	0.057	0.180	0.665	0.171	0.058	0.234	0.521
Philippines	(PHIL)	-0.018	0.074	0.268	0.656	0.176	0.063	0.170	0.839	0.077	0.056	0.286	0.606	0.161	0.047	0.220	0.671
Poland	(POL)	-0.112	0.117	0.247	0.383	0.105	0.086	0.314	0.514	-0.025	0.057	0.187	0.619	0.259	0.048	0.222	0.362
Romania	(ROM)	0.111	0.095	0.356	0.228	-0.023	0.078	0.308	0.093	-0.143	0.039	0.286	0.127	-0.061	0.051	0.219	0.240
Russian Fed	(RUS)	na	na	na	na	na	na	na	na	-0.390	0.065	0.236	0.401	-0.104	0.072	0.189	0.515
South Africa	(SAF)	0.100	0.105	0.267	0.266	0.077	0.087	0.191	0.325	0.012	0.077	0.153	0.213	0.141	0.075	0.161	0.267
Turkey	(TUR)	0.207	0.085	0.264	0.331	0.257	0.070	0.231	0.482	0.140	0.063	0.241	0.376	0.164	0.056	0.239	0.494
Uruguay	(URU)	-0.141	0.081	0.146	0.562	0.317	0.075	0.122	0.889	0.299	0.062	0.137	0.672	0.134	0.058	0.155	0.637
Venezuela	(VEN)	-0.124	0.133	0.206	0.586	0.020	0.100	0.211	0.651	0.249	0.081	0.169	0.661	0.132	0.075	0.184	0.431

Table A3

Summary Table Control Group

		1980-84				1985-89				1990-94				1995-99			
Country	+	x(t)	rn(t)	j(t)	h(t)	x(t)	rn(t)	j(t)	h(t)	x(t)	rn(t)	j(t)	h(t)	x(t)	rn(t)	j(t)	h(t)
China	(CI)	na	0.11	na	0.03	0.21	0.03	0.36	0.12	0.22	0.05	0.38	0.18	0.17	0.04	0.39	0.18
Cezch Republic	(CK)	na	na	na	na	0.04	0.10	0.27	0.14	-0.16	0.08	0.25	0.24	-0.03	0.08	0.32	0.39
Estonia	(ESTO)	na	na	na	na	na	na	na	na	-0.12	0.03	0.26	0.15	0.10	0.05	0.27	0.45
Hunghary	(HUNG)	-0.03	0.10	0.28	0.49	-0.03	0.08	0.27	0.70	-0.23	0.07	0.21	0.64	0.03	0.08	0.28	0.58
India	(IN)	0.21	0.02	0.24	0.15	0.20	0.03	0.25	0.24	0.14	0.05	0.24	0.32	0.20	0.06	0.25	0.26
Kuwait	(KW)	-0.10	0.10	0.16	0.47	0.47	0.07	0.13	0.43	1.28	0.06	0.17	0.87	-0.08	0.08	0.12	0.58
Lebanon	(LB)	na	na	na	na	na	na	na	na	0.25	0.06	0.27	0.34	0.01	0.10	0.36	0.37
Malaysia	(MAL)	0.11	0.07	0.36	0.46	0.10	0.07	0.28	0.71	0.37	0.06	0.38	0.50	0.05	0.06	0.37	0.45
Saudi Arabia	(SARA)	-0.12	0.12	0.25	0.14	0.01	0.07	0.19	0.20	0.13	0.07	0.21	0.16	-0.01	0.08	0.19	0.20
Slovenia	(SLO)	na	na	na	na	na	na	na	na	-0.21	0.09	0.18	0.32	0.11	0.05	0.24	0.36
Tunisia	(TU)	0.10	0.06	0.33	0.48	0.04	0.05	0.24	0.48	0.11	0.05	0.28	0.60	0.13	0.05	0.27	0.63
United Arab Emirates	(UAE)	-0.09	0.14	0.28	0.22	0.02	0.08	0.24	0.36	0.15	0.06	0.25	0.45	0.08	0.05	0.27	0.46
Zimbawe	(ZW)	0.16	0.08	0.2	0.27	0.18	0.07	0.17	0.03	0.05	0.06	0.21	0.53	0.08	0.04	0.22	0.69

REFERENCES

Alba, Pedro et al. (1999), "The Role of macroeconomics and financial sector linkages in East Asia's financial crisis", in Pierre-Richard Agénor, Marcus Miller, David Vines and Axel Weber, (ed.), The Asian Financial Crisis, Cambridge University Press.

Corbett, J.and D. Vines (1999), "The Asian crisis: lessons from the collapse of financial systems, exchange rates and macroeconomic policy", in Pierre-Richard Agénor, Marcus Miller, David Vines and Axel Weber, (ed.), The Asian Financial Crisis, Cambridge University Press.

Corsetti, G., P. Pesenti and N. Roubini, (1999), "The Asian Crisis: an overview of the empirical evidence and policy debate", in Pierre-Richard Agénor, Marcus Miller, David Vines and Axel Weber, (ed.), The Asian Financial Crisis, Cambridge University Press.

Fleming, Wendell H. and Jerome L. Stein (1999), “A Stochastic Optimal Control Approach to International Finance and Foreign Debt”, CESifo Working Paper # 204, available at http://www/CESifo.de

Fleming, Wendell H. and Jerome L. Stein (2001), “Stochastic Inter-temporal Optimization in Discrete Time”, in Negishi, T., Rama Ramachandran and Kazuo Mino (ed.), Economic Theory, Dynamics and Markets: Essays in Honor of Ryuzo Sato, Kluwer. An earlier version is available as CESifo Working Paper #338, available at http://www/CESifo.de

Infante, Ettore and Jerome L. Stein (1973),”Optimal Growth with Robust Feedback Control”, Review Economic Studies, XL(1)

International Monetary Fund, (1999) ,International Capital Markets, Washington DC

International Monetary Fund, (1999).Anticipating Balance of Payments Crises, Occasional Paper #186,

Stein, Jerome L. and Giovanna Paladino (1997) “Recent Developments in International Finance: A Guide to Research”, Journal of Banking and Finance 21 (11-12).