No. 2149

A KRUGMAN-DOOLEY-SACHS THIRD GENERATION MODEL OF THE ASIAN FINANCIAL CRISIS

Gregor Irwin and David Vines

INTERNATIONAL MACROECONOMICS

Centre for Economic Policy Research

ISSN 0265-8003

A KRUGMAN-DOOLEY-SACHS THIRD GENERATION MODEL OF THE ASIAN FINANCIAL CRISIS

Gregor Irwin and David Vines

Discussion Paper No. 2149
May 1999

Centre for Economic Policy Research
90–98 Goswell Rd
London EC1V 7RR
Tel: (44 171) 878 2900
Fax: (44 171) 878 2999
Email: cepr@cepr.org

CEPR Discussion Paper No. 2149

May 1999

ABSTRACT

A Krugman-Dooley-Sachs Third Generation Model of the Asian Financial Crisis*

This paper presents a multiple-equilibrium model of the Asian financial crisis. The economy has Krugman-style over-investment caused by weak financial regulation and exacerbated by government guarantees. Following Dooley, the government only has a limited capacity or willingness to honour such guarantees. The model has a unique long-run equilibrium, with over-investment. But in the short run, in which the capital stock is fixed, it also has multiple equilibria. If lenders regard lending as low-risk, then it is. But if they regard lending as high-risk then the cost of honouring guarantees rises, making the lending high-risk and the risk premium self-justifying. We argue that this model usefully captures the ideas of panic and collapse which have been popularised in Sachs' discussions of the Asian crisis.

JEL Classification: E44, F34, O16
Keywords: financial crisis, Asian economic crisis, over-investment, multiple equilibrium

Gregor Irwin and David Vines
Institute of Economics and Statistics
Manor Road
Oxford, OX1 3UL
UK
Tel: (44 1865) 271 067
Fax: (44 1865) 271 094
Email: gregor.irwin@economics.ox.ac.uk
david.vines@economics.oxford.ac.uk

*We are grateful to Mike Dooley, George Fane, Ken Kletzer, Marcus Miller, and Hyun Shin for helpful discussions.

Submitted 23 April 1999

NON-TECHNICAL SUMMARY

This paper presents a multiple-equilibrium model of the Asian financial crisis. It is designed to combine insights from Krugman (1998), Dooley (1999a, 1999b) and Sachs (1995, 1996).

In the immediate aftermath of the crisis, debate raged about whether this was a problem of panic and collapse, resulting from a shift from a 'good' equilibrium to a 'bad' one (Radelet and Sachs, 1998) or a problem resulting from a worsening of fundamentals (Krugman, 1998). Krugman has since generously conceded defeat (Krugman, 1999). But in our view (and Krugman's) a good panic-and-collapse account of the Asia crisis should be one which is underpinned by a story about what it was in the financial system that made a bad equilibrium possible. This Radelet and Sachs did not provide. The present paper provides one possible candidate for that story.

Krugman's account of the failings of the Asian financial system, released on the web very early into the crisis (Krugman, 1998), presented his idea of 'Pangloss over-investment'. He suggested that, in an economy with government guarantees which ensure bailouts for investments that make losses, investors would over-invest to the point where the marginal product of capital in the best state of the world had fallen to the world interest rate. The end result is inefficient, but this falls short of providing a story of crisis if taxpayers can be persuaded to go on paying for the bailouts. It certainly does not provide the basis of a story of panic and collapse.

Dooley provides the missing link between Krugman's Pangloss investment and a multiple-equilibrium model of panic and collapse. In a prescient paper written long before the crisis began, he argued that the Asian miracle was, in effect, organised theft, and that it might well end in a crisis. Using an informal argument he suggested that the amount available for government pay-outs is limited and that once the government capacity to pay up on guarantees is exhausted there would be a crisis.

In this Paper we combine the insights from these three strands of analysis in a formal model. To get the essential ideas across, we set the story up as a series of static, one-shot games played over time. There are Krugman style investors, a government with a limited capacity (or willingness, see below) to pay up on guarantees if things go bad and stochastic shocks in the environment (because we think that the arrival of a negative external shock is an essential part of the Asia Crisis story). Lenders – foreign banks – have rational expectations. They thus understand the government's problem, and they build a risk premium into the price at which they are to lend to the country

(as there is a probability that the government will not be able or willing to bail them out).

We analyse the evolution of events in a crisis-prone ‘Asian’ economy as follows. Initially there are no guarantees, and lending by foreign banks is risky. This is because there is the possibility of productivity shocks to the economy which impact on the ability of investors (‘financial intermediaries’) to pay interest on debt; this is the only risk which we explicitly identify. As a result, the initial level of the capital stock is low. One day the government sets up shop offering to bail out people whose investments go wrong and guarantee repayments to foreign banks. This drives down the equilibrium interest rate and creates additional investment opportunities with *potentially* positive profits. As a result capital gradually accumulates, moving towards the Pangloss equilibrium, at which point the marginal product in the best state of the world would be equal to the world interest rate.

Because of short-run inflexibility of the stock of capital – due to adjustment costs – there is always the following risk. The economy has at any point in time a particular stock of capital. Suppose also that the equilibrium interest rate is equal to the world rate. Let there be a shock to the economy. Then, by assumption, if the productivity outcome is a bad one, the government can afford to pay the guarantees. There is, by assumption, no risk of default, which is why the interest rate can be in equilibrium at the low world level. However with this set-up there is also another equilibrium with a much higher interest rate. At such a higher level of the interest rate there are a range of productivity shocks bad enough to provoke the government to renege on its guarantees, and so to induce a crisis. This is why the high interest rate is also an equilibrium. Thus in this set-up there is a short-run, ‘bank run’ problem. With low interest rates no productivity shock can be bad enough to cause the government not to pay up on its guarantees. But with high interest rates it is much more difficult for the government to pay up, so the probability of not being able to do so is much greater, thus validating the risk premium which is the reason for the high interest rates. Hence this model has a self-fulfilling crisis possibility, the reason for which is the endogeneity of the risk premium on loans to the country. This enters non-linearly into the model, in such a way as to give the possibility of two equilibria, in exactly the same way that expectations of exchange rate collapse enter into the multiple-equilibria currency crisis models.

Interestingly, this multiple-equilibrium feature of the model is a feature of the short-run, but not of the long-run. In the long-run, high interest rates mean that much less capital is invested in the country, and this effect is strong enough to mean that the costs of paying out on the guarantees in the high interest case would be no higher than in the low interest rate case, thus removing the problem. But the realistic assumption that there is a ‘short-run’ – in which risk

premia can be instantly adjusted but in which the capital stock is effectively predetermined – means that the model *is* one which is vulnerable to an equilibrium problem.

In this model a crisis is inevitable, even if its timing is unpredictable, *once the initial guarantee is introduced*. Following the introduction of a guarantee which is (at least partially) credible the long-run equilibrium debt stock and output both rise, and growth increases as capital gradually accumulates. But as soon as the capital stock and debt rise above the pre-guarantee level, multiple short-run equilibria exist with the result that a crisis is possible. If the government is forced to renege on its guarantee, following a switch to the bad equilibrium and the realisation of a low productivity shock, the long-run equilibrium once again reverts to the pre-guarantee position as the government can no longer credibly underwrite repayments to foreign banks. In such a crisis the capital stock shrinks and output contracts sharply.

1. Introduction and Summary

This paper presents a multiple-equilibrium model of the Asian financial crisis. It is designed to combine insights from Krugman (1998), Dooley (1999a, 1999b), and Sachs (1995, 1996)[1].

The East Asian financial crisis has been truly remarkable in more ways than one. Suddenly the "Asian miracle" became the "Asian crisis". But, more than this, the existing models of *currency* crisis were powerless to explain what had happened. This was not a "first generation" currency crisis brought about by excess budget deficits, as in Krugman (1979). Nor was the crisis caused by a conflict between the austerity needed to defend a fixed exchange rate and the expansion needed to remove high unemployment, as in Britain's forced exit from the ERM in 1992. To understand whatever happened to Asia, a new "third generation" model is needed, which puts crisis in the financial system at centre-stage.

In the immediate aftermath of the crisis, debate raged about whether this "third generation" crisis was a problem of panic and collapse, resulting from a shift from a "good" equilibrium to a "bad" one (Radelet and Sachs, 1998) or a problem resulting from a worsening of fundamentals (Krugman, 1998). Krugman has generously conceded defeat: "I was wrong" (Krugman, 1999, p 1). But in our view (and Krugman's) a good panic and collapse account of the Asia crisis should be one which is underpinned by a story about what it was in the financial system that made a bad equilibrium possible. This Radelet and Sachs did not provide. The present paper provides one possible candidate for that story.

Krugman's by-now-famous account of the failings of the Asian financial system, released on the web very early into the crisis (Krugman, 1998), presented to the world his idea of "Pangloss over-investment". He suggested that we think of a representative Asian country as having a downward-sloping demand curve for capital and facing a given world interest rate, and that we model Asian "crony capitalism" as government guarantees which ensure bailouts for investments that make losses. In the absence of such guarantees, investors would add to the capital stock to the point where the marginal product of capital had fallen to the world interest rate. But in the presence of guarantees, investors would over-invest, to the point where the marginal product of capital *in the best state of the world* had fallen to the world

[1] See also Radelet and Sachs (1998)

interest rate. The reason for this is that unexploited profit opportunities would remain if investment was not pushed this far: in a bad state of the world investors would stand to lose nothing (because of the bail-out provision), but in a good state investors would make profits in excess of their interest obligations. The trouble with this story is that it is not necessarily a story of crisis, if taxpayers can be persuaded to go on paying for the bailouts. It certainly does not provide the basis of a story of panic and collapse.

Michael Dooley's prescient paper, presented in late 1993 (and forthcoming as Dooley, 1999a), provides the missing link. Dooley argued that the Asian miracle was, in effect, organised theft, and that it might well end in a crisis. Dooley suggested that Asian governments had essentially set themselves up to pay out on the kind of guarantees which Krugman later described (although he did not specify the downward-sloping demand for capital as Krugman later did). But – in a crucial addition – he suggested that the amount available for such pay-outs was limited. Adjustment costs would mean that investors could not steal the money immediately. But in the end – he thought – they would set up enough projects with negative expected returns to walk away with the state's capacity to pay out rewards. When that happened, there would be a crisis.

To summarise: Radelet and Sachs gave no good story of their multiple-equilibrium claims; Krugman's paper contained one really good idea, not very well worked out; and Dooley's central argument was entirely informal. The present paper contains an attempt to put all of these ideas together. It is set out as follows. The next sub-section sketches the model set-up and summarises our argument. Then a short additional introductory sub-section justifies our multiple-equilibrium approach, and discusses briefly the relationship between financial crisis and currency crisis. The roles of financial intermediaries, the government, and foreign banks in our basic model are set out in section 2. The model is solved in section 3, first for the long run and then for the short run. Section 4 considers dynamic adjustment between the short run and the long run. In Section 5 we consider how such a formal model might be used as an aid to the understanding of financial crises. Section 6 concludes by discussing some possible extensions.

1.1 The Argument Summarised

To get the essential ideas across, we set the story up as a series of static, one-shot games played over time. There are Krugman style investors. There is a government with a limited capacity (or willingness, see below) to pay up on guarantees if things go bad. We model stochastic shocks in the environment, like Krugman implicitly suggested we need to. We do this because we think that the arrival of a negative external shock is an essential part of the Asia Crisis story.[2] The lenders – foreign banks – have rational expectations. They thus understand the government's problem, and they build a risk premium into the price at which they are to lend to the country. (They do this because, as Dooley suggests, there is a probability that the government will not be able or willing to bail them out.)

We analyse the evolution of a crisis in a crisis-prone "Asian" economy as follows. Initially there are no guarantees, and lending by foreign banks is risky. This is because there is the possibility of productivity shocks to the economy which impact on the ability of borrowers ("financial intermediaries") to pay interest on debt; this is the only risk which we explicitly identify. As a result, the initial level of the capital stock is low. One day the government sets up shop offering to bail out people whose investments go wrong and guarantee repayments to foreign banks. This means that at the given world interest rate there are now extra investment opportunities with *potentially* positive profits. As a result capital gradually accumulates, moving towards the "Pangloss" equilibrium, at which point the marginal product in the best state of the world would be equal to the world interest rate.

It is possible that this "Pangloss equilibrium" is the long-run equilibrium of the system: if the government was able – or willing – to afford all of the losses which would be incurred in bad states. Alternatively if this implicit fiscal obligation were to become too large, rational foreign banks would build a premium into the interest rate which they demanded over and above the world interest rate; as a result the long-run equilibrium of the capital stock would be less high. In Section 3.1 of the paper we characterise the long-run equilibrium of the system, showing how it depends on the willingness-to-bail-out and other parameters, and we show that it is unique.

[2] By doing this we answer in the affirmative the question posed by Kletzer (1999) in his comment on the Dooley paper. Kletzer called for formalisation of the paper in order to see if the Dooley story requires, for completeness, to be located in a stochastic world. We think that it does.

In Section 3.2, and subsequently, we explore the panic-and-crisis feature of such a set-up. Because of the short-run inflexibility of the stock of capital – due to adjustment costs – there is always the following risk. The economy has at any point of time a particular stock of capital. Suppose also that the equilibrium interest rate is equal to the world rate. Let there be a shock to the economy. Then, by assumption, if the productivity outcome is a bad one, the government can afford to pay the guarantees. There is – by assumption – no risk of default, which is why the interest rate can be in equilibrium at the low world level. However with this set-up there is also another equilibrium with a much higher interest rate. At such a higher level of the interest rate there are a range of productivity shocks bad enough to provoke the government to renege on its guarantees, and so to induce a crisis. This is why the high interest rate is also an equilibrium. Thus in this set-up there is a short-run, "bank run", problem. With low interest rates no productivity shock can be bad enough to cause the government not to pay up on its guarantees. But with high interest rates it is much more difficult for the government to pay up, so the probability of not being able to do so is much greater, thus validating the risk premium which is the reason for the high interest rates. Hence this model has a self-fulfilling crisis possibility, the reason for which is the endogeneity of the risk premium on loans to the country. This enters non-linearly into the model, in such a way as to give the possibility of two equilibria, in exactly the same way that expectations of exchange rate collapse enter into the multiple-equilibria currency crisis models (about which Krugman has been so critical).

Interestingly, this multiple-equilibrium feature of the model is a feature of the short-run, but not of the long-run. In the long-run, high interest rates mean that much less capital is invested in the country, and this effect is strong enough to mean that the costs of paying out on the guarantees in the high interest case would be no higher than in the low interest rate case, thus removing the problem. But the realistic assumption that there is a "short-run" – in which risk premia can be instantly adjusted but in which the capital stock is effectively predetermined – means that the model *is* one which is vulnerable to an equilibrium problem.

1.2 Why Multiple Equilibria and What of Currency Crises?

It is worth conceding immediately that our multiple-equilibrium approach to the analysis of panics is a contested one. Both Krugman (1996) and Dooley (1998) have been deeply critical of it. Dooley's complaints are worth quoting in detail:

> "The absence of clear thinking on this issue, and the failure to develop fundamentals-based models which illuminate it, ha[s] led to the growth of a plethora multiple equilibrium models, of which there are too many, none of which are properly testable, not least because they do not 'model' the data. A return to fundamentals based models really is advisable, partly in order to re-check whether any model exists which will actually fit the data. The modelling challenge now is to try to construct a new generation of 'first generation' fundamentals-based models which will meet this test. Multiple equilibrium models may be mathematically interesting. However they are almost certainly unnecessary." (Comments by Dooley, reported in Global Economic Institutions, 1998, p 14).

Morris and Shin (1998, 1999) are also critical: :

> "the multiple equilibrium approach is vulnerable to the charge that it does not fully explain a currency attack, since the shift in beliefs which leads to the shift from one equilibrium to another is left unexplained. In short, there is an indeterminacy in the theory" (Morris and Shin, 1999, p 3)

As a result, these authors choose to model the panic-and-collapse issue in a different way. They focus on a particular form of strategic complementarity between speculators; the expected profitability to one speculator from selling depends positively on the number of other speculators who are selling. They argue that as a result of this there can be "break-points": on one side of a particular level of the "fundamentals" a system is safe, but immediately beyond this level the system spectacularly collapses.

Nevertheless we believe (and now Krugman does too) in opposition Morris and Shin and (on this issue) to Dooley, that the multiple-equilibrium approach is important. No lesser persons than Stan Fischer and Joe Stiglitz, respectively First Deputy Managing Director of the IMF and Chief Economist of the World Bank, have made multiple-equilibrium models the basis of their proposals for reform of the international monetary and financial system. (Fischer, 1999, Stiglitz, 1998) As Fischer, expanding on the role of a crisis manager, writes:

> "In a panic, it is necessary to find some means for dealing with the collective action problem. *A panic is the realisation of a bad equilibrium when a good equilibrium is possible*, and there is a need in such situations for some agency or group of institutions to take the lead in trying to steer the economy to the good equilibrium." (Fischer, 1999, p 3, italics added)

In this paper we do not have any good theory of how or why the economy might flip from the good equilibrium to the bad one (let alone any theory of what a crisis manger might do in response to this). But, in everyday life we readily admit that we have no good theory of why a particular driver ends up dead in a motorway pileup while her friend, who left home at the same time, arrives safely. To argue simply that "such a view runs against our theoretical scruples against indeterminacy" (Morris and Shin, p 3) seems to imply a very particular philosophy of science. We stick – for the present – to our view that multiple-equilibrium approaches, such as the one that we present, can be illuminating, even if incomplete.[3]

In two related papers, one of us has presented an extensive informal account of the Asian crisis which focuses on the interconnections between financial and currency crisis, and argues that the crisis became so severe *because* of these interconnections. (Corbett and Vines, 1999a,b) The critical extra feature resulting from this interconnection was – we argue – that the fixed exchange rate regimes pursued in Asia before the crisis induced massive unhedged borrowing in foreign currency. When the currency depreciated this raised the burden of that borrowing and led to a worsening of the financial crisis. In the present paper our purpose is more limited, focused, and formal. We put currency crises entirely to one side, and instead seek to explore formally the underpinnings of the financial crisis. We do this because we think that the story in this paper describes what happened at the onset of the crisis.

2. The Basic Model

We assume production is Cobb-Douglas in form:

$$Y = AK^{\alpha}L^{1-\alpha}$$

where $A \sim U[0,1]$ is a productivity shock, realised after investment decisions are made, and K and L are capital and labour inputs.

[3] Our modelling strategy is thus diametrically opposed to that of Morris and Shin. Unlike Morris and Shin we do not model quantity interactions between speculators, but instead we focus on strategic interactions between lenders ("foreign banks") and the government. Also, instead of operating, as they do, in "quantity space", we operate in "price space": we place the risk-premium-adjusted interest-parity condition at the core of our analysis. Our problem with the Morris and Shin approach – with which we otherwise have a lot of sympathy – is that so far it has been applied only in a model with very sparsely specified economic features. Including an endogenous risk premium – which is at the centre of our treatment – within the strategic interactions of their model at present looks to be ferociously difficult. But if it could be done the resulting picture could be very useful.

All productive capital is owned by (many) domestic financial intermediaries who finance the entire capital stock by borrowing from foreign banks. We make three key assumptions about this debt.

(i) The principal is always recoverable.[4]

(ii) Financial intermediaries make interest payments if they have the necessary funds to do so. To the extent that they have insufficient funds they can default without cost (effectively we assume that bankruptcy costs are zero).

(iii) Initially the government guarantees the debt of financial intermediaries by promising to make up any shortfall in the interest payment. This obligation might turn out to be extremely costly and so the guarantee may not be fully credible. As we shall see, the guarantee does not directly influence the behaviour of financial intermediaries (who do not care if they default on interest payments), but it does reduce the interest rate at which foreign banks are willing to lend, and so indirectly influences the investment decisions of financial intermediaries.

To keep the model simple we assume labour is supplied inelastically. With the labour supply normalised to one we can write:

$$Y = AD^{\alpha}$$

where D is the debt stock.

In this model there are three key groups – financial intermediaries, the government, and foreign banks – each of which are examined in turn below.

2.1. Financial Intermediaries

Financial intermediaries make profits, π, when the capital share of output exceeds interest payments to foreign banks:[5]

$$\pi = \alpha AD^{\alpha} - rD \tag{1}$$

Realised profits depend critically on the productivity shock, A. But as the owners of financial intermediaries suffer no penalty if their company makes a loss, all sources of *potential* profit will eventually be exploited, even if the *expected* profit is negative. This is Krugman's

[4] This is a strong simplifying assumption which, as will be discussed later, requires that all capital goods can be exported and re-sold internationally.

[5] In a competitive labour market workers receive real wages equal to their marginal product.

"Pangloss investment", which in this model results from zero bankruptcy costs and a zero capital requirement (this is a poorly regulated financial sector). As we shall see, government guarantees exacerbate this over-investment problem as they push down the equilibrium interest rate.

We can use this condition to pin down the debt stock in the long run; given equation (1) and the distribution of *A* the potential profit on new investment is driven to zero when,

$$D^{LR} = (\alpha / r)^{\frac{1}{1-\alpha}} \tag{2}$$

where the superscript indicates that this is the long run level of the debt stock. We assume that the debt stock adjusts slowly to this level, but in the short run it may diverge from D^{LR}. At any given point in time we write the debt stock as:

$$D = (k\alpha / \bar{r})^{\frac{1}{1-\alpha}} \tag{3}$$

where $\bar{r}$ is the risk-free world interest rate (exogenous and constant) and k is a measure of the divergence of *D* from the long-run level. When $D = D^{LR}$ we must have $k = \bar{r} / r$; in a long-run equilibrium with $r = \bar{r}$ we have $k = 1$.

2.2. Government

Initially the government guarantees the interest payments of financial intermediaries to foreign banks. If the government honours the guarantee, it must raise sufficient funds through taxation to pay for this. From (1) the taxation cost of the guarantee is:[6]

$$T = rD - \alpha A D^{\alpha} \tag{4}$$

This commitment might turn out to be extremely costly, in particular if *r* is high and/or *A* is low (a bad productivity shock). Alternatively, we assume the government can choose to renege on the guarantee, but if it does so it must pay a one-off fixed cost equal to *V*. As this is a one-off cost, reneging by the government absolves it of all future commitments to foreign banks.

[6] *T* can be regarded as a lump-sum tax on the labour force. The linear form of equation (4) has been chosen for analytical convenience. More generally, to the extent that taxes are distortionary, higher taxation will have a negative effect on output. Also, following a low productivity shock which reduces output, raising a given level of taxation will be more difficult, as both *MPL* and wages fall. Both factors suggest that raising higher taxes will become progressively more difficult.

V can be regarded as the political cost of reneging on the guarantee. Such an action is likely to be costly as it will reduce the credibility of the government, not just in the eyes of foreign banks, but in all policy areas. Alternatively, V can be regarded as the cost to the government of falling out with its "cronies" in the financial sector who benefit from the low interest rate that results from a credible guarantee.

The government effectively faces an optimal stopping problem. Each period it can either renege and pay the one-off cost, V; or alternatively it can honour the guarantee and pay the taxation cost T. If it takes this second course of action the government incurs an additional liability equal to the expected present cost of the guarantee in the subsequent period. We represent the problem for the government as choosing the action which minimises the following cost function:

$$C_t^G(r_t, D_t, A_t) = \min\left[V, T_t + \delta E_t C_{t+1}^G(r_{t+1}, D_{t+1}, A_{t+1} \mid r_t, D_t)\right] \tag{5}$$

where δ is the discount factor, T is the taxation cost of honouring the guarantee (given by (4)), and $E_t C_{t+1}^G(\cdot)$ is the expected cost of the guarantee next period if the government honours the guarantee this period. Note that the maximum value of $E_t C_{t+1}^G(\cdot)$ is V. From (5) the government will renege on the guarantee this period if:

$$T_t > V - \delta E_t C_{t+1}^G(\cdot) \tag{6}$$

This optimal stopping problem is extremely complicated. In this paper we simplify the analysis by assuming $\delta = 0$. In doing so we make the analysis tractable, but at the expense of ignoring one channel through which r and D affect the behaviour of the government. Correcting for this assumption will require more work.[7]

Given $\delta = 0$, using (4) and (6), we find that the government will only fulfil the guarantee when the productivity shock is above a threshold level, $\tilde{A}$. Specifically:

$$\tilde{A} = \begin{cases} 0 & \text{when} \quad V \geq rD \\ (r/\alpha)D^{1-\alpha} - (V/\alpha)D^{-\alpha} & \text{when} \quad rD - \alpha D^{\alpha} < V < rD \\ 1 & \text{when} \quad V \leq rD - \alpha D^{\alpha} \end{cases} \tag{7}$$

[7] Alternatively we can derive qualitatively similar results by assuming the government always believes r and D will remain unchanged in future periods (see section 6 for more detail).

This trigger value for the productivity shock, $\tilde{A}$, is non-decreasing in the interest rate and the debt stock, but non-increasing in the political cost of reneging on the guarantee.

2.3. Foreign Banks

Foreign banks lend elastically to financial intermediaries at a mark-up over the risk-free world interest rate:

$$r = \bar{r}/(1-q) \tag{8}$$

where $0 \le q \le 1$ is the expected percentage default on the interest payment. This condition must hold continuously as foreign banks are assumed to be competitive and risk neutral; banks are unable to charge a higher rate, even when productivity is high, as we assume financial intermediaries can change lender at any time without cost.

The expected percentage default will depend both on the expected revenues of financial intermediaries and the probability that the government will honour its guarantee. Suppose foreign banks believe the government will honour the guarantee when actual productivity is above a threshold level $\hat{A}$. In this case the percentage default expected by foreign banks is:

$$\begin{aligned} q &= \frac{1}{rD}\int_0^{\hat{A}} (rD - \alpha A D^{\alpha})dA \\ &= \hat{A} - (\alpha \hat{A}^2 D^{\alpha-1})/(2r) \end{aligned} \tag{9}$$

By substitution into (8) we get:

$$r = \frac{2\bar{r} - \alpha \hat{A}^2 D^{\alpha-1}}{2(1-\hat{A})}$$

3. Model Solution

The model is closed with the equilibrium condition that $\hat{A} = \tilde{A}$ and so we can re-write the interest rate as:

$$r = \frac{2\bar{r} - \alpha \tilde{A}^2 D^{\alpha-1}}{2(1-\tilde{A})} \tag{10}$$

In the long run we have three unknowns – D, $\tilde{A}$, and r – and the same number of conditions governing their behaviour – conditions (2), (7), and (10). In the short run the debt stock is given by equation (3) and so there are just two unknowns. In this section we analyse the model solution in the long run, and then the short run, before integrating the analysis in section 4.

3.1. Long-Run Equilibrium

In the long run investment exhausts all potential sources of profit, so that the debt stock is given by equation (2). By substitution into (10):

$$r = \left[\frac{2}{2(1-\tilde{A}) + \tilde{A}^2} \right] \bar{r} \tag{11}$$

Over the relevant range – $0 \le \tilde{A} \le 1$ – this function is non-decreasing in $\tilde{A}$, with $\bar{r} \le r \le 2\bar{r}$. From (3) it follows that $1/2 \le k \le 1$ at the long-run equilibrium. $\tilde{A}$ equals one in the absence of a government guarantee, and so $r = 2\bar{r}$ with $k = 1/2$ (this provides a useful reference point when we consider the implications of introducing a guarantee in sections 4 and 5). As $\tilde{A}$ decreases, k increases, until $k = 1$ when $\tilde{A} = 0$ and the government guarantee is fully credible.

By substitution of (2) into (7) we can write:

$$\tilde{A} = \begin{cases} 0 & \text{when} \quad V \ge r^{-\frac{\alpha}{1-\alpha}} \alpha^{\frac{1}{1-\alpha}} \\ 1 - (V/\alpha)(r/\alpha)^{\frac{\alpha}{1-\alpha}} & \text{when} \quad 0 < V < r^{-\frac{\alpha}{1-\alpha}} \alpha^{\frac{1}{1-\alpha}} \\ 1 & \text{when} \quad V \le 0 \end{cases} \tag{12}$$

$\tilde{A}$ is non-increasing in r, because in the long run higher interest rates cause financial intermediaries to reduce their debt levels, lowering the cost of the guarantee, and thus making fulfilment of the guarantee more likely.

We now have two relationships which must hold in the long-run equilibrium: equation (11) shows how foreign banks set the interest rate as a function of the trigger value, $\tilde{A}$; and (12) shows how the government's trigger value changes with the interest rate. We can plot both functions on the same diagram to determine the equilibrium point of intersection; an example

of an interior solution is shown in figure 1 below. Although it is not possible to derive a reduced form solution, we can deduce that, for all $V > 0$, there is necessarily a unique equilibrium in which $\tilde{A} < 1$. This follows as r is non-decreasing in $\tilde{A}$, whilst $\tilde{A}$ is non-increasing in r. Taken together, and given that $\tilde{A}(r)$ is defined for all $r > 0$, this is sufficient to ensure a unique point of intersection.

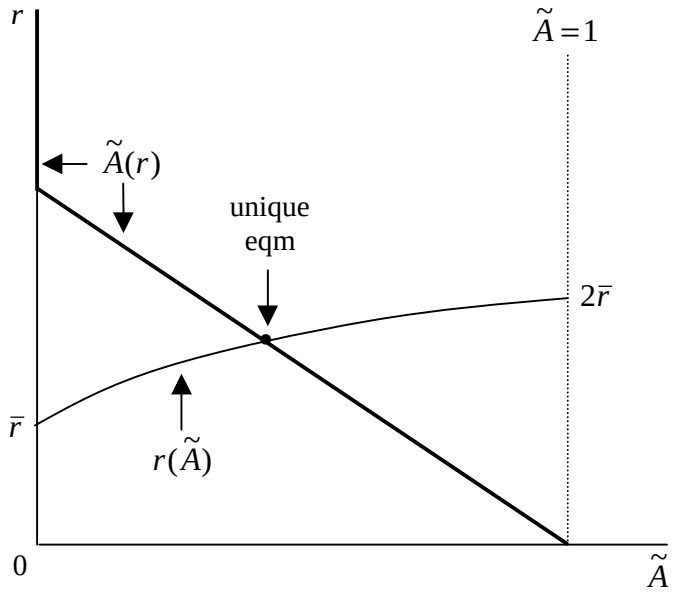

Figure 1

In figure 1 we have shown an interior solution. From (11), if we have a boundary solution with $\tilde{A} = 0$, then $r = \bar{r}$ (this makes sense as $\tilde{A} = 0$ means the government guarantee is fully credible). From (12) we can write the condition for the boundary solution as:

$$V \geq \bar{r}^{-\frac{\alpha}{1-\alpha}} \alpha^{\frac{1}{1-\alpha}} \tag{13}$$

The unique long-run equilibrium is therefore a boundary solution if the political cost of reneging on the guarantee is sufficiently high, otherwise the unique equilibrium will be an interior solution for which there is a positive probability, *ex ante*, that the government will renege on the guarantee. For expositional purposes we assume in the rest of this paper that the long-run equilibrium is a boundary solution and so this condition holds. This convenient assumption has no fundamental effect on the conclusions of the analysis.

3.2. Short-Run Equilibrium

In the short run the debt level is fixed. By substitution of (3) into (7):

$$\tilde{A} = \begin{cases} 0 & \text{when} \quad V \geq r(k\alpha/\bar{r})^{\frac{1}{1-\alpha}} \\ (rk/\bar{r}) - (V/\alpha)(\bar{r}/k\alpha)^{\frac{\alpha}{1-\alpha}} & \text{when} \quad r(k\alpha/\bar{r})^{\frac{1}{1-\alpha}} - \alpha(k\alpha/\bar{r})^{\frac{\alpha}{1-\alpha}} < V < r(k\alpha/\bar{r})^{\frac{1}{1-\alpha}} \\ 1 & \text{when} \quad V \leq r(k\alpha/\bar{r})^{\frac{1}{1-\alpha}} - \alpha(k\alpha/\bar{r})^{\frac{\alpha}{1-\alpha}} \end{cases} \tag{14}$$

From (14), with *D* fixed in the short run, the function $\tilde{A}(r)$ is non-decreasing in *r*. In the short run higher *r* increases the interest liabilities of financial intermediaries without any off-setting reduction in the debt stock (as in the long run).

By substitution of (3) into (10) the interest rate is:[8]

$$r = \left[\frac{2k - \tilde{A}^2}{2k(1-\tilde{A})} \right] \bar{r} \tag{15}$$

From the previous section we know that, without any government guarantee, $k = 1/2$ at the long-run equilibrium. Following the introduction of a guarantee which is (at least partially) credible, $1/2 < k \leq 1$ at the long-run equilibrium.

When $k = 1/2$ equation (15) reduces to $r = (1+\tilde{A})\bar{r}$ and, given (14), it is straightforward to show that there is a unique short-run equilibrium. This equilibrium will be a boundary solution with $r = \bar{r}$ when:

$$V \geq \bar{r}^{-\frac{\alpha}{1-\alpha}} (\alpha/2)^{\frac{1}{1-\alpha}} \tag{16}$$

This condition is weaker than (13) and so we assume it holds.

When $k > 1/2$ the function $r(\tilde{A})$ is continuous within the domain $[0,1)$, tends to infinity as $\tilde{A} \to 1$, and has positive first and second derivatives. This means that for high *V* we have two equilibria, but for low *V* we may have no equilibrium. In the intermediate case there is a single value of *V* for which we have a unique equilibrium. The possibility of multiple equilibria is demonstrated in figure 2.

---

[8] Equation (15) is not defined when $\tilde{A} = 1$, except in the special case where $k = 1/2$, in which case $r = 2\bar{r}$. From (14), given $r = 2\bar{r}$, the strategy $\tilde{A} = 1$ only makes sense for the government when $V = 0$.

In figure 2 we have marked a "good" equilibrium with low r and $\tilde{A}$, and a "bad" equilibrium with higher r and $\tilde{A}$. The good equilibrium is a boundary solution with $r = \bar{r}$ when:

$$V \geq \bar{r}^{-\frac{\alpha}{1-\alpha}} (k\alpha)^{\frac{1}{1-\alpha}} \tag{17}$$

For lower values of V we may have two interior solutions. Condition (17) is weaker than (13) for all $1/2 < k < 1$ and so we assume this condition holds.

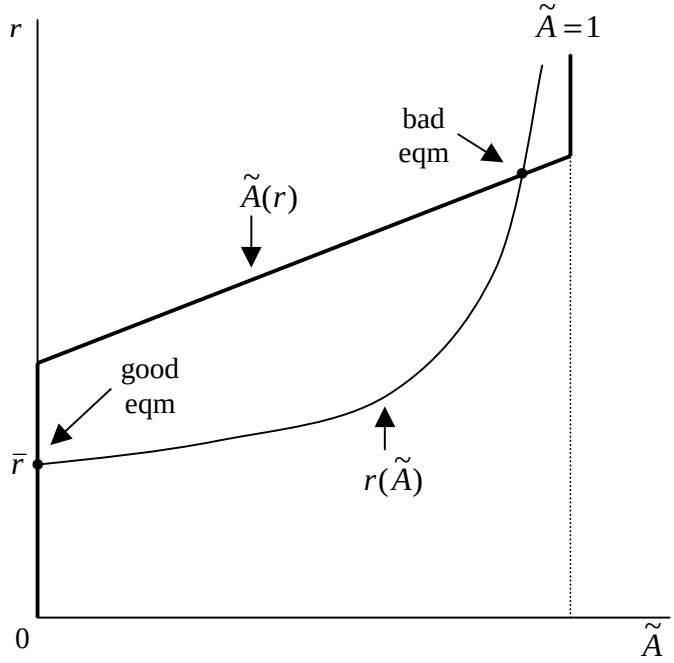

Figure 2

It is possible to derive a complete reduced form short-run solution by simultaneously solving equations (14) and (15) for r and $\tilde{A}$. The algebra and a summary of the results are presented in the appendix.

4. Dynamic Adjustment

In figure 3 we show both short-run and long-run equilibria in r, D space for the specific case where $V = 6$, $\alpha = 0.5$ and $\bar{r} = 5\%$ (these results have been obtained by simulation).[9] These parameter values satisfy condition (13). The D^{LR} locus traces out the long-run equilibrium debt stock as a function of the interest rate (equation (2)). The arrows indicate that when the debt stock is below this level it must be increasing over time. Conversely, when the debt stock is above this level it must be decreasing over time.

[9] The bad equilibrium locus has been truncated at $r = 25\%$. In the limit as k approaches $1/2$, $r = 34\%$.

At the long-run equilibrium, without any government guarantee, $r = 2\bar{r} = 10\%$, $\tilde{A} = 1$ and $k = 1/2$. With a government guarantee (positive *V*) the long-run equilibrium interest rate is below this level (and the implied value for *k* is correspondingly higher); if *V* is sufficiently high so that condition (13) is satisfied the unique long-run equilibrium interest rate is $r = \bar{r}$, $\tilde{A} = 0$ and $k = 1$. This condition holds for the chosen parameter values.

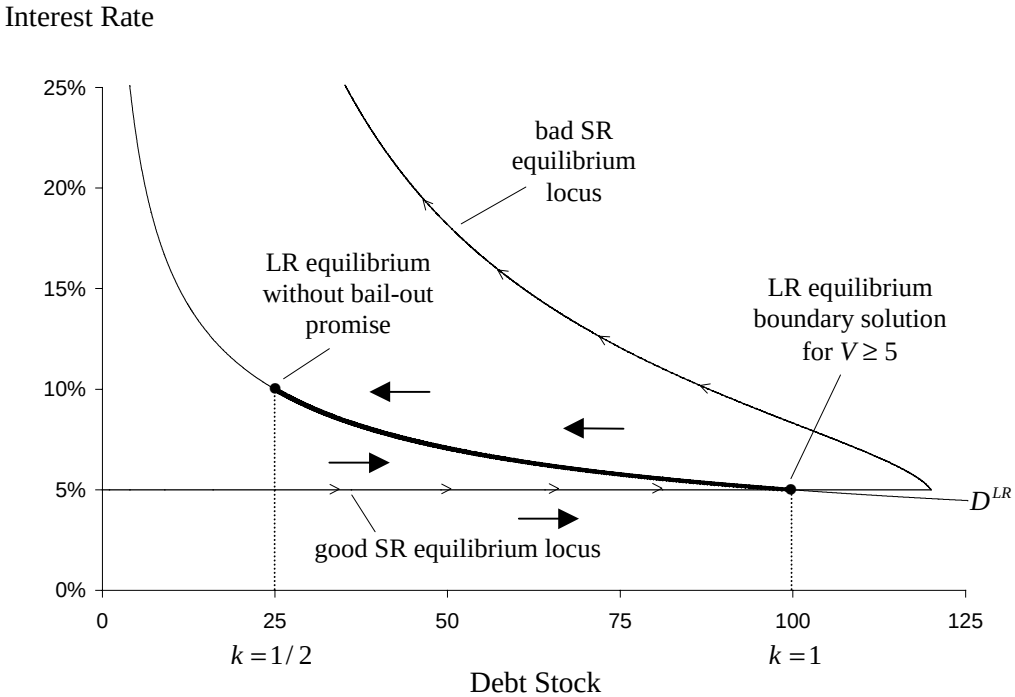

Figure 3 $V = 6$, $\bar{r} = 5\%$, $\alpha = 0.5$

Suppose that, starting from the long-run equilibrium without a guarantee at $k = 1/2$, the government announces that it will henceforth guarantee all interest obligations of financial intermediaries. Furthermore, suppose that foreign banks understand that the political cost to the government of failing to stand by this promise is $V = 6$. What is the effect of such a policy in the short run and the long run?

In the short run, with $V = 6$, a unique equilibrium exists at $k = 1/2$ with $r = \bar{r}$ and $\tilde{A} = 0$ (this is a boundary solution as condition (16) holds). As the debt stock is now below the implied long-run equilibrium level it rises (higher *k*). For $k > 1/2$ two equilibria exist, as shown by the two separate loci in figure 3 (the good equilibrium locus is a horizontal line at $\bar{r}$ as (17) holds for all *k* within the relevant range). The dynamics of the model are complicated by the multiple short-run equilibria: in the good equilibrium the debt stock is

increasing and will converge with the long-run equilibrium; but in the bad equilibrium, corresponding to the upper locus, the debt stock is decreasing and therefore moves away from the long-run equilibrium.

In this model we cannot say which of the short-run equilibria will be realised at any particular point, but it is plausible that the good equilibrium is more likely for a sustained period following the introduction of the guarantee. To get this result we need to make two arbitrary, but intuitively appealing assumptions:

(i) In the absence of any shift in government policy, discrete jumps in the interest rate are less likely than continuous changes.

(ii) The probability of switching between multiple equilibria is decreasing in the size of the jump.

With $k = 1/2$ the unique equilibrium has $r = \bar{r}$. For all higher k the good short-run equilibrium interest rate is the same, as it is in the long-run equilibrium. The first assumption therefore means that the good equilibrium is more likely to be realised than the bad equilibrium. Over time D increases and the gap between the good and bad equilibrium interest rates decreases (this should be clear from figure 3). The second assumption therefore implies that the probability of switching to the bad equilibrium will increase over time.

5. Understanding Financial Crises

In this model a financial crisis is inevitable, even if its timing is unpredictable. To understand this consider figure 3 once again. Suppose that the cost to the government of reneging on the bail-out policy is $V = 6$. Immediately following the introduction of this policy the interest rate falls to $\bar{r}$ (this is the unique equilibrium with $k = 1/2$). This causes the debt stock to rise as financial intermediaries exploit the greater profit potential available at the lower interest rate. Given that $\tilde{A} = 0$ when $r = \bar{r}$ the government stands by its promise to bail out any losses for sure. As the debt stock rises (and so k rises) multiple equilibria exist, but as we argued in the previous section the good equilibrium is more likely. If $r = \bar{r}$ the debt stock will continue to rise towards the long-run equilibrium level with $k = 1$. Both during this transition, and at the long-run equilibrium itself, multiple equilibria exist, with the possibility of a switch to the bad equilibrium.

What is a financial crisis in this model? A switch to the bad equilibrium is painful for the government, but this in itself may fall short of a full "crisis". In this model a crisis occurs when the government cannot stand by its guarantee and is forced to renege. This is only possible when $\tilde{A} > 0$, and with $V = 6$ this is only true for the bad equilibrium. Even in this case, however, a very high productivity shock may save the government; it is only when the productivity shock is below $\tilde{A}$ that the government reneges.

Why does reneging precipitate a crisis? The high debt level in this economy is driven by a reduction in the interest rate as foreign banks expect a lower default rate on interest payments given the government guarantee. By assumption, if the government ever reneges, it pays a one-off political cost; subsequently the government faces no additional penalty should it fail to compensate foreign banks for further default by financial intermediaries. Effectively, then, following a crisis V returns to zero and the long-run equilibrium debt stock falls so that $k = 1/2$. A lower debt stock means a lower capital stock and therefore lower output. A key characteristic of the financial crisis, then, is a collapse in output which follows from the discrete jump in the long-run equilibrium when the government is forced to renege.[10]

Why is a crisis inevitable? Once the guarantee is introduced the interest rate is depressed and financial intermediaries have an incentive to take out more debt and increase investment. At higher debt levels multiple equilibria exist. Even though initially the good equilibrium may be more likely than the bad equilibrium, we can never rule out the possibility of a switch to the bad equilibrium. At the bad equilibrium there is a non-zero probability of a crisis occurring in which the government is forced to renege on its guarantee. If such a crisis occurs we move to a new long-run equilibrium at $k = 1/2$ (the pre-guarantee equilibrium). The crisis is inevitable because as soon as the guarantee is introduced the multiplicity of equilibria occurs and this persists until the government is forced to renege. Even if the probability of crisis at any particular time is low, a crisis must occur eventually with probability equal to one.

6. Extensions

[10] This raises the question of how adjustment to the new long-run equilibrium will occur. Immediately following the crisis there is an excess supply of capital goods. We have assumed that the debt principal is not at risk and this requires that capital goods can be resold without any loss in value. This requires that capital goods can be exported abroad, and that the economy is relatively small so that such exports do not depress the international price of capital goods.

In this paper we have demonstrated how a government guarantee to underwrite losses in a poorly-regulated financial sector (zero capital requirements, zero bankruptcy costs) can lead to over-investment. This over-investment creates multiple equilibria: a good equilibrium in which interest rates are low and there is a high probability (in the above case, unity) that the government can keep its promise; and a bad equilibrium with higher interest rates and a positive (perhaps high) probability that the government is forced to renege. In the last section we described how a financial crisis can occur, in which high interest rates force the government to renege, leading to a collapse in the capital stock and long-run output as foreign banks withdraw their funds.

There are three main areas for further research, both in tying-up loose ends and in understanding the implications of the model.

(i) Relaxing the assumption that the government does not care about the future and so properly endogenising *V*. This is a complicated problem. We can show that if the government believes *r* and *D* will be unchanged in future periods the model solution is not changed in any interesting way. The only significant difference is that (other things being equal) higher *V* will be required for the government to keep its promise – for example, condition (13) must be "re-scaled" so that:

$$V \geq \left(\frac{2-\delta}{2(1-\delta)} \right) r^{-\frac{\alpha}{1-\alpha}} \alpha^{\frac{1}{1-\alpha}}$$

(ii) Relaxing the assumptions of zero bankruptcy costs and zero capital requirements, and the assumption of zero risk on the debt principal.

(iii) Understanding the policy implications of the model: how can the potential for crises be avoided; how can the government act to avoid crisis when the potential exists; and how should the government (and international organisations) respond when crises occur?

Appendix. Reduced Form Short-Run Equilibrium

We can solve for the interior solution(s) by substitution from (14) into (15) and solving for *r*. A necessary condition for an interior solution is that:

$$V^2 \geq \alpha^2 (k\alpha / \bar{r})^{\frac{2\alpha}{1-\alpha}} (2k-1) \tag{A1}$$

Note that condition (A1) is not as strong as (17). If this condition is satisfied then, subject to the additional constraints placed on the interior solution by (14) (*i.e.* that there is no boundary solution; see discussion below), the interior solutions are:

$$r = (\bar{r} / k)(1 \pm \Omega) \qquad \text{where} \qquad \Omega = \sqrt{1 - 2k + (V/\alpha)^2 (\bar{r} / k\alpha)^{\frac{2\alpha}{1-\alpha}}} \tag{A2}$$

When condition (A1) holds with equality there is a unique short run equilibrium with $r = \bar{r} / k$ which coincides with the long-run equilibrium for $1/2 \leq k \leq 1$.

Given (A2) we can substitute for *r* back into (14) to determine whether each root satisfies the relevant range condition for an interior solution. In the case of the positive root this is an equilibrium interest rate for $1/2 < k < 1$, but for higher *k* this requires:

$$V > \bar{r}^{-\frac{\alpha}{1-\alpha}} (k\alpha)^{\frac{1}{1-\alpha}} \tag{A3}$$

The positive root cannot be an equilibrium interest rate for $k < 1/2$. Note that condition (A3) is stronger than (A1). In the case of the negative root, given condition (A1), this is only an equilibrium interest rate when $k < 1$ and the following condition is satisfied:

$$V < \bar{r}^{-\frac{\alpha}{1-\alpha}} (k\alpha)^{\frac{1}{1-\alpha}} \tag{A4}$$

The reduced form solution is summarised in tables 1 to 3 below.

Range for V	**Equilibria**	**Relevant Condition**
$V < \bar{r}^{-\frac{\alpha}{1-\alpha}} (k\alpha)^{\frac{1}{1-\alpha}}$	Unique equilibrium $r = (\bar{r} / k)(1 - \Omega)$, $\tilde{A} > 0$	(A4)
$V \geq \bar{r}^{-\frac{\alpha}{1-\alpha}} (k\alpha)^{\frac{1}{1-\alpha}}$	Unique equilibrium $r = \bar{r}$, $\tilde{A} = 0$	(17)

Table 1: $k \leq 1/2$

Range for V	Equilibria	Relevant Condition(s)
$V < \alpha(k\alpha/\bar{r})^{\frac{\alpha}{1-\alpha}}\sqrt{2k-1}$	No equilibrium	(A1)
$V = \alpha(k\alpha/\bar{r})^{\frac{\alpha}{1-\alpha}}\sqrt{2k-1}$	Unique equilibrium $r = r^{LR} = \bar{r}/k$, $\tilde{A} > 0$	(A1), (A2)
$\alpha(k\alpha/\bar{r})^{\frac{\alpha}{1-\alpha}}\sqrt{2k-1} < V$	Good equilibrium $r = (\bar{r}/k)(1-\Omega)$, $\tilde{A} > 0$	(A4)
$V < \bar{r}^{-\frac{\alpha}{1-\alpha}}(k\alpha)^{\frac{1}{1-\alpha}}$	Bad equilibrium $r = (\bar{r}/k)(1+\Omega)$, $\tilde{A} > 0$	(A1), (A2)
$V \geq \bar{r}^{-\frac{\alpha}{1-\alpha}}(k\alpha)^{\frac{1}{1-\alpha}}$	Good equilibrium $r = \bar{r}$, $\tilde{A} > 0$	(17)
	Bad equilibrium $r = (\bar{r}/k)(1+\Omega)$, $\tilde{A} > 0$	(A1), (A2)

Table 2: $1/2 < k < 1$

Range for V	Equilibria	Relevant Condition(s)
$V < \bar{r}^{-\frac{\alpha}{1-\alpha}}(k\alpha)^{\frac{1}{1-\alpha}}$	No equilibrium	(17), (A3)
$V = \bar{r}^{-\frac{\alpha}{1-\alpha}}(k\alpha)^{\frac{1}{1-\alpha}}$	Unique equilibrium $r = \bar{r}$, $\tilde{A} = 0$	(17)
$V > \bar{r}^{-\frac{\alpha}{1-\alpha}}(k\alpha)^{\frac{1}{1-\alpha}}$	Good equilibrium $r = \bar{r}$, $\tilde{A} > 0$	(17)
	Bad equilibrium $r = (\bar{r}/k)(1+\Omega)$, $\tilde{A} > 0$	(A3)

Table 3: $k \geq 1$

References

Agenor, Richard, Marcus Miller, David Vines, and Axel Weber (1999) *The Asian Financial Crises: Causes, Contagion, and Consequences.* Cambridge: Cambridge University Press.

Corbett, J. and D. Vines (1999a) "Asian Currency and Financial Crises: Lessons from Vulnerability, Crisis, and Collapse", forthcoming in *World Economy,* January 1999.

Corbett, J. and D. Vines (1999b) "The Asian Crisis as Vulnerability and Collapse in the Traverse between Two Types of Capitalism" forthcoming in Agenor, Miller, Vines and Weber (1999)

Dooley, M. P. (1999a)"Are Recent Capital Inflows to Developing Countries a Vote for or Against Economic Policy Reforms?" Working Paper #295 University of California Santa Cruz, 1994. Published in *Exchange Rates, Capital Flows, and Monetary Policy in a Changing World Economy*, William Gruben, David Gould, and Carlos Zarazaga, eds., Kluwer Academic Publishers, Boston, 1997, pp. 211-221, and forthcoming in a revised form in Agenor, Miller, Vines and Weber (1999)

Dooley, M. P. (1999b) "A Model of Crisis in Emerging Markets", University Of California Santa Cruz, 1997, forthcoming.

Fischer, S (1999) "On the need for an International Lender of Last Resort". Paper presented to the annual meetings of the American Economic Association and available at http://www.imf.org/external/np/speeches/1999/010399.HTM

Global Economic Institutions (1999) "Financial Crises: Contagion and Volatility: Report of a Conference held in London on 8-9 May 1998", in *Newsletter* of the Global Economic Institutions Research Programme, No 8, October. London: Centre for Economic Policy Research

Kletzer, K. (1999) "Comment" on Dooley (1999a), forthcoming in Agenor, Miller, Vines and Weber (1999)

Krugman, (1996) P. "Are Currency Crises Self-Fulfilling?" in Bernanke,-Ben-S.; Rotemberg,-Julio-J., eds. NBER Macroeconomics Annual. Cambridge and London: MIT Press, pages 345-78.

Krugman, P. (1998) "Whatever Happened to Asia?" http://web.mit.edu/krugman/www/DISINTER.html

Krugman, P. (1999) "Balance Sheets, the Transfer Problem, and Financial Crises" http://web.mit.edu/krugman/www/FLOOD.pdf

Morris, S. and H. S. Shin (1998) “Unique Equilibrium in a Model of Self-Fulfilling Currency Attacks” *American Economic Review*, vol 88, pp 587 – 597.

Morris, S. and H. S. Shin (1999) “A Theory of the Onset of Currency Attacks” forthcoming in Agenor, Miller, Vines and Weber (1999)

Radelet, S. and J. Sachs (1998) “The Onset of the East Asian Crisis” (mimeo, Harvard University)

Sachs, J. (1995) “Do we need a Lender of Last Resort?” Frank D. Graham Lecture, Princeton University, April.

Sachs, J. (1996) Alternative Approaches to Financial Crises in Emerging Markets *Revista-de-Economia-Politica*, vol 16, no. 2, April-June, pages 40-52.

Stiglitz, J. (1998) “Must Financial Crises Be This Frequent and This Painful?” forthcoming in Agenor, Miller, Vines and Weber (1999)