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ABSTRACT

Self-fulfilling and Self-enforcing Debt Crises*

We distinguish two attitudes towards debt. The attitude of prudent borrowers, which attempt to stabilize their debts to low levels, even in the event of a bad shock, and what we call, after Krugman, "Panglossian" borrowers, which only focus on the best of their growth prospects, and rationally anticipate to default on their debt when hit by a bad shock. We show empirically that this distinction is consistent with the data. Past a threshold of risk which, we show, corresponds to a spread of about 450 basis points, countries fail to respond to bad shocks and let their risk drift accordingly. We also distinguish two types of debt crises. Those which are the effect of an exogenous shock, and those which are self-fulfillingly created by the financial markets themselves. We show that the large majority of crises are of the first kind, although the probability of self-fulfilling cases is not negligible.

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1 Introduction

International debt crises are (very) costly. Why do we observe that so many countries fall in their trap? Shouldn't we expect a more prudent behavior from these countries? The theoretical answer is actually that: it depends. Take the simplest form of a financial crisis driven by an exogenous shock. Spreads on sovereign bonds are high because the country is expected to be vulnerable to an earthquake or to a long lasting commodity shock which is beyond its control. The country should then indeed behave more prudently: the more debt would the country have to repay, the heavier would be the cost of the earthquake, relatively to the good state of nature. Yet, on the other hand, if the expected earthquake is so large that the country knows that it will actually default on its debt, then a "Panglossian attitude" (as Krugman coined it) may become rational: the debt will lose all value after the earthquake, and it would then be absurd not to borrow more, beforehand. Depending on the initial value of the debt and the parameters driving the risk of the exogenous shock, a country may either behave "very" prudently or instead simply ignore the financial risk. In the latter case, debt leads to debt: we call it the self-enforcing case.

Let us now consider the cases when crises are driven by the lack of confidence of financial markets towards a given country, self-fulfillingly making the country financially fragile. Self-fulfilling debt crises have been analyzed in different forms. In the model of Cole and Kehoe (2000), self-fulfilling crises are a variant of a liquidity crisis, by which a lack of coordination among creditors leads a solvent country to default. As argued by Chamon (2007), however, such crises can readily be avoided, when lenders manage to make contingent offers, of the kind that are performed by venture capitalists. If any individual creditor offers a line of credit, conditionnally on other creditors following suit, then liquidity crises can readily be avoided.

Self-fulfilling crises have also been analyzed as the perverse outcome of a snowball effect through which the build up of debt becomes unmanageable, out of the endogenous fear that it can indeed become unmanageable (Calvo, 1988). Relying on an intuition developed in a simpler model in Cohen and Portes (2004), we show that snowball spirals can only occur in cases where a debt crisis has the potential of reducing the fundamental of the indebted country. If a crisis reduces, say by 10%, the GDP of a country, then it is clear that the lack of confidence towards a country can degenerate into a self-fulfilling crisis. If instead the fundamentals are not altered by the crisis, we show that self-fulfilling crises of the Calvo type are (theoretically) impossible.

At the end of this argument, we chose to focus on a simple characterization of a self-fulfilling debt crisis as one which is the outcome of an endogenous weakening of the country's fundamentals. In the self-fulfilling case so defined, it is the crisis that reduces GDP, out of the various disruptions that a weakening of the confidence in a country may bring (capital flight, exchange rate crisis...). In the "earthquake case", the sequence goes the other way around: the fundamentals are first destroyed, then the crisis occurs.

From the theoretical model that we present, a simple typology of cases can be reached. Below a critical level of debt, a country tends to act prudently, aiming for instance to reduce its debt in response to a permanent bad shock. Past a critical level of the debt-to-GDP ratio, which can be the outcome of a sequence of repeated bad shocks, a country will start behaving in a Panglossian way, rationnally ignoring the bad news, self-enforcingly raising the level of debt to its upper limit. A crisis can then occur, either because a bad exogenous shock happens, or out of a self-fulfilling shock, one that endogenously weakens the ability of a country to service its debt.

It is such typology that we attempt to bring to the data. We use a slightly modified version of the data base that has been compiled by Kraay and Nehru (2004), which we updated to cover all debt crises that occurred between 1970 and 2004. Following and adapting Kraay and Nehru (2004), we show that the likelihood of a debt crisis is well explained by three factors: the debt-to-GDP ratio, the level of real income per capita, and a measure of overvaluation of domestic currency. We then show that there is a level of debt crisis risk below which a country does behave prudently, cancelling (after three years) the effect of a good or of a bad news on its debt-to-GDP ratio. Past a threshold instead, we show that an indebted country lets its risk drift, with no correcting force seemingly at work. This corresponds to the self-enforcing case.

In order to estimate the risk of a self-fulfilling debt crisis, we then distinguish the law of motion of debt in tranquil times from the motion that is set once the crisis has started. We define a self-fulfilling crisis as one that would not have happened, had debt simply been driven by the pre-crisis path. We find that self-fulfilling crises, so defined, correspond to a small minority of cases. In average, there is less than a fifth of debt crises that appear to be self-fulfilling. This is clearly not negligible, however, and deserves to be taken seriously.

The paper proceeds as follows. In section 2, we set up an infinite horizon model, which we solve in section 3, in which we analyse the logic of each crisis. We then turn in section 4 to the presentation of the data upon which our econometric analyses rely. In section 5, we describe the econometric model used to estimate the likelihood of either type of crisis, and we present the results in section 6.

2 A Panglossian theory of debt

2.1 The economy

Let us consider a one good exchange economy. Output at time t is written Q_t. We assume that output follows a Markovian process whose transition matrix can be described as follows:

$$\begin{aligned} Q_t &= (1+g)Q_{t-1} \quad \text{with probability} \quad 1-p \\ Q_t &= (1-\gamma)Q_{t-1} \quad \text{with probability} \quad p \end{aligned}$$

We think of the event of probability $1-p$ as normal time, with g the corresponding (positive) growth rate of the economy. The transition of probability p corresponds to a recession, which we take in the sequel to be severe enough to warrant the risk of a debt crisis (see below). We shall assume that the loss of output γ is itself the product of two terms:

$$(1-\gamma) = (1-\gamma_1)(1-\gamma_2) \tag{1}$$

We take the first term, γ_1, to be the outcome of an exogenous shock, say a commodity shock or an earthquake. The second term, γ_2, only occurs in case of a debt crisis. This can be thought of as the effect of an exchange rate crisis and/or of capital flight that disrupts the economy. In the sequel, we shall distinguish a third term, λ, which measures the (residual) ability of lenders to impose sanctions on a defaulting country. While sanctions can be monitored (and delayed) by creditors, we shall assume that the cost γ_2 cannot be prevented, being the result of non coordinated actions of small private investors[1].

In the sequel, we shall assume that the bad shock is of a magnitude γ that is severe enough (relatively to the good shock) to lead to a risk of crisis when it occurs. Technically, we shall need as a condition that:

$$\gamma + g > p \tag{2}$$

2.2 The financial markets

We assume that the country may have access to world financial markets where the riskless rate is a constant r. We assume that debt is short-term and needs to be refinanced every year.

[1]This model provides a rich enough variety of results to keep it simple as it is. It could readily be furthered by making growth endogenous as in Cohen (1993, 1995).

The timing of events comes as follows. First assume that the country has incurred a debt obligation, D_t, falling due at time t, and has not defaulted in previous years. At the beginning of time t, the country discovers the shock that it is exposed to. It then learns the value of Q_t. It then either defaults on its debt, or reimburses it.

If the debt is reimbursed, the country can borrow a new loan L_t, which has to be repaid at time $t+1$, for an amount D_{t+1}. In order to avoid coordination problems, we assume, following Chamon (2007), that creditors can commit on L_t and D_{t+1} before the decision to default is made, conditionnally on the decision not to default being made. We define the risk-adjusted interest paid by the country as the solution to:

$$D_{t+1} = (1 + \varrho_{t+1})L_t$$

Such financial deals being made, the country eventually consumes, in the event of non default:

$$C_t = Q_t + L_t - D_t$$

When instead the country defaults, we assume that it suffers forever after a negative productivity shock of magnitude λ and is further constrained to financial autarky. In other words, post-default imposes:

$$C_t^d = (1 - \lambda)Q_t$$

Furthermore, we shall assume for the time being that that no payment is performed after a default (this is relaxed below when we deal with the case of a negotiated settlement). Clearly default will only happen in case of a bad news, that is following a recession.

2.3 Preferences

The decision to default or to stay in the financial markets involves a comparison of two paths that involve expectations over the entire future. In order to address this problem, we assume that the country seeks to solve:

$$J(D_t, Q_t) = \max_{\{C_s\}_{s\geq t}} E_t \left\{ \sum_{s=t}^{\infty} \beta^{(s-t)} u(C_s) \right\}$$

D_t can be negative if the country builds foreign asset.

Formally, we can write:

$$J(D_t, Q_t) = \max_{C_t} \{u(C_t) + \beta(1-p)J[D_{t+1}, (1+g)Q_t] + \beta p\, J[D_{t+1}, (1-\gamma)Q_t]\}$$

in which the value of γ depends on the occurence of a debt crisis (such as defined in (1)).

We shall call:

$$J_d(Q_t) = E_t \left\{ \sum_{s=t}^{\infty} \beta^{(s-t)} u((1-\lambda)Q_s) \right\}$$

the post-default level of utility, which becomes, by definition, independent of debt.

We shall assume that:

$$u(x) = \frac{x^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}}$$

where σ is the intertemporal elasticity of substitution.

Let us write $\beta = \frac{1}{1+\delta}$, where δ is the discount rate. In the sequel, we shall assume that:

$$\delta > r - \frac{g}{\sigma} \tag{3}$$

This condition makes the country a potential debtor (see sections 3.1 and 3.2).

Given the isoelasticity of the utility function, we shall define the critical values of debt that set the risk of a debt crisis as a fraction of GDP. Let us define here two such critical ratios as:

$$z_t = \frac{D_t}{Q_{t-1}}$$

and:

$$d_t = \frac{D_t}{Q_t}$$

The z ratio is an advance predictor of a debt problem. The d ratio is the contemporaneous one. Depending on the realization of a shock, a country can then switch from an initial value of z_t to a high or a low value of d_t which is either $\frac{z_t}{1+g}$ or $\frac{z_t}{1-\gamma}$. The next section analyzes where the country ends up, depending on its preferences and upon the shocks that it is exposed to over the course of its history.

3 Equilibrium

3.1 The riskless path

In order to analyze the debt dynamics of a country, let us first analyze a hypothetical scenario, when the country is indefinitely offered the riskless rate of interest. This corresponds to a case (whose internal consistency will be checked afterwards) where the country supposedly manages to never take the risk of a debt crisis, keeping permanently its debt ratio low enough to avoid the risk of a default.

The problem in that case boils down to:

$$\begin{aligned} J(D_t, Q_t) &= \max_{C_t} \big\{ u(C_t) + \beta(1-p) J\left[(1+r)(D_t + C_t - Q_t), (1+g)Q_t\right] \\ &\quad + \beta p\, J\left[(1+r)(D_t + C_t - Q_t), (1-\gamma)Q_t\right] \big\} \end{aligned}$$

Call $q_t = -\frac{\partial J}{\partial D_t}(D_t, Q_t)$ the marginal utility of wealth. Call q_{t+1}^+ its subsequent value in case of a good shock, and q_{t+1}^- its subsequent value in case of a bad shock.

The Euler conditions are written as:

$$q_t = \beta(1+r)[(1-p)q_{t+1}^+ + pq_{t+1}^-] \tag{4}$$

$$u'(C_t) = q_t$$

Let us now characterize two "pseudo steady states" associated with an infinite sequence of good shocks for the first one, and with an infinite sequence of bad shocks for the other one.

Let us first analyze the outcome of an infinite sequence of good shocks. We note z_∞^+ the associated value of the z ratio. Moreover, the ratio $\theta_t = \frac{q_t^-}{q_t^+}$ will converge towards the following limit (using a first order approximation):

$$\theta_\infty^+ = \frac{\delta + p - r + \frac{g}{\sigma}}{p}$$

Since $\theta_\infty^+ \geq 1$, this pseudo steady state exists if and only if:

$$\delta > r - \frac{g}{\sigma}$$

which is the assumption that we adopted above in equation (3). Were this condition not satisfied, the country would actually indefinitely build up reserves while in the good state of nature, in order to offset the potential cost of moving into a recession. This is a feature that may have a bearing with the behavior of large reserve holders today, but clearly sets no risk of a debt crisis.

In the case where z_∞^+ exists, which we now assume, the country will be happy to service its debt in full rather than defaulting upon it, if $J\left(\frac{z_\infty^+}{1-\gamma}, 1\right) \geq$

$J_d(1)$ (since J is homogenous of degree $1 - \frac{1}{\sigma}$). Otherwise, the country actually tries to take too much debt to be consistent with the no-repudiation constraint.

Even in the case where the country would be happy to service its debt, if hit by a long sequence of good shocks, it may still happen that bad shocks turn the country's behavior towards repudiation. In order to analyze this case, we characterize the other "pseudo steady state" associated with an infinite sequence of bad shocks. We note z_∞^- the limit of the z ratio in that case, observing that we must have $z_\infty^+ < z_\infty^-$. Moreover, the limit of the ratio θ_t will be in that case:

$$\theta_\infty^- = \frac{1-p}{1+\delta-p-r-\frac{\gamma}{\sigma}}$$

Since $\theta_\infty^- \geq 1$, this pseudo steady state exists if and only if:

$$\delta < r + \frac{\gamma}{\sigma}$$

Otherwise, if this latter condition is not satisfied, the country facing extremely bad conditions will enter a debt spiral, ending up in the danger zone.

In order to check if all outcomes allow the country to be offered a riskless rate of interest, we need to make sure that the country will not decide to default, even in the worse case scenario of an infinite sequence of bad shocks. This will be the case if z_∞^- exists and is such that $J\left(\frac{z_\infty^-}{1-\gamma}, 1\right) \geq J_d(1)$. If starting say from below z_∞^-, the country stabilizes its debt in the range $[\,z_\infty^+,\, z_\infty^-]$. Even if hit by an infinite sequence of bad shocks, the country will never enter the danger zone. It will never allow a build up of debt to put its solvency at risk, even after a large number of bad shocks.

On the other hand, if either z_∞^- does not exist, or if $J\left(\frac{z_\infty^-}{1-\gamma}, 1\right) < J_d(1)$, then the country will necessary prefer to default rather than servicing its debt, if hit by a long enough sequence of bad shocks.

To summarize, two cases are possible:

- Either the riskless strategy is a long run equilibrium, whatever the shocks: this is the case if z_∞^- exists and is such that $J\left(\frac{z_\infty^-}{1-\gamma}, 1\right) \geq J_d(1)$
- Either a riskless strategy is possible, but not necessarily sustainable in the long run: this happens in the opposite case. If starting from a low enough level of debt, the country aims at stabilizing its debt, but may be forced to abandon this riskless strategy if hit by a repeated sequence of bad shocks. In this case it is necessary to study the risky strategy, which we discuss in next section.

3.2 The risky trajectory

Let us now analyze what happens once debt has entered into a "risky zone", which we define as one where the country would default if hit by a bad shock, and keep servicing the debt if hit by a good shock. The upper limit to a country's outstanding debt in such case can be computed using the incentive constraint (see appendix A). Using a first order approximation, this limit is:

$$d_+ = \frac{\lambda}{r - g + p}$$

We can correspondingly define two z ratios. One is the upper limit of z itself, defined as:

$$z_+ = \frac{\lambda(1+g)}{r - g + p}$$

which allows the country to absorb a good shock but not a bad one. One can also define the ratio z_- below which the country can absorb at least one bad shock, so that it is regarded as riskless until the bad shock occurs. This is the ratio:

$$z_- = \frac{\lambda(1-\gamma)}{r - g + p}$$

Clearly, there are two corresponding values for the z and the d, depending on whether we plug the value γ or γ_1 in the equation. This will set the risk of a multiple equilibrium below. At this stage we only consider the largest value of γ as the parameter that drives the country's decisions. This corresponds to the expectation that the market will always pick up the bad equilibrium, when there is a choice.

Under this assumption, let us analyze what happens when the country has reached the point where one more bad shock would trigger default. In that case the optimal trajectory is a solution to:

$$\begin{aligned} J(D_t, Q_t) &= \max_{C_t} \big\{ u(C_t) + \beta(1-p) J[(1+\varrho)(D_t + C_t - Q_t), (1+g)Q_t] \\ &\quad + \beta p \, J_d[(1-\gamma)Q_t] \big\} \end{aligned} \tag{5}$$

in which J_d is the post-default path.

The risk-adjusted rate of interest is worth:

$$1 + \varrho = \frac{1+r}{1-p} \tag{6}$$

which corresponds to the zero profit condition of lenders.

The first order conditions are now:

$$q_t = \beta(1+r)q_{t+1} \tag{7}$$

$$u'(C_t) = q_t$$

In that case, the risk of default is no more internalized in the Euler equation (7), while it was in the riskless case (see equation (4)). This arises from the fact that default leads the country to a level of welfare which is independent of the amount of debt it has accumulated.

Under assumption (3), there is no interior solution to the long-run debt pattern. Passed the threshold z_-, the country, in that case, takes as much debt as it can on the long-run, that is here up to the z_+ level.

In that case, there is a strong discontinuity between the riskless and the risky trajectory. In the risky trajectory, the pattern of debt becomes explosive (after some time) and brings the country to the limit. In that case, the country does not attempt to stabilize debt in response to a default risk, it is exactly the opposite which happens: the default-penalty makes the country Panglossian. This is the self-enforcing case that we alluded to in the introduction.

3.3 Default or not default

In the analysis of the previous section, we have considered the case of a country which has reached a level of debt past which it would rather default in the event of a bad shock. As discussed in section 3.1, however, it may happen that this will never be the case, even in circumstances where $z_t > z_-$. This relates to a point which is emphasized by Cole and Kehoe (2000) (although in the different context of a sunspot equilibrium): a country in danger of a bad shock may be willing to adjust to move out of the danger zone. In other words, $z_t > z_-$ is a necessary but not a sufficient condition for a country to be in danger (see appendix A for further details). In order to see why and how this may happen, let us consider here the upper limit of debt that can be computed by making the pessimistic assumption of a negative growth rate $-\gamma$, with a rate of interest corresponding to the riskless rate r. This gives:

$$d_s = \frac{\lambda}{r+\gamma}$$

For any level of debt below d_s, the country would certainly not prefer default, to the extent that it can stabilize debt at a lower cost than default, even in the most pessimistic case where the negative shock would occur indefinitely. d_s is therefore a lower bound to the upper limit of a riskless strategy.

Now consider condition (2): $\gamma + g > p$. This assumption is equivalent to $d_s < d_+$. The country can take more debt by running the risk of default. Clearly, if this condition does not hold, the country will never want to take the risk of default, even though it may find itself to the right of the threshold d_+, provided at least that its debt is below d_s.

Let us then briefly comment on the opposite case $\gamma + g < p$ for which the country will never embark itself into the market of risky debt. This may be the outcome of two opposite situations. One corresponds to a case where both γ and g are small. Neither the growth rate nor the cost of a crisis are large enough to warrant a risky approach. It is simpler for the country to adopt a conservative view of the future, taking more debt only when (*i.e.* after) the good shock occurs. This case corresponds to mature economies which are neither high on their growth prospects nor seriously affected by downturns when they happen.

Another scenario is one in which p is the high value parameter. This corresponds to countries which are too volatile to access the market of risky debt, having to pay a risk premium that would be too high. This corresponds to the other end of the spectrum, of highly volatile debtors, which are barred from the emerging bond market.

This is why, as a proxy for the case where the analysis of section 3.2 is relevant, we shall restrict our empirical investigation to the subgroup of emerging countries with market access (at a spread).

3.4 The risk of multiple equilibria

There are many potential sources of multiple equilibria in the model that we deal with. One has obviously to do with the endogenous nature of the shock of magnitude γ. Before dwelling on it, let us first review the other sources that have been dealt with in the literature.

One potential source is the risk of a snowball effect à la Calvo (1988). Take a country which borrows L_t at time t, and is offered a riskless rate because of the fact that:

$$L_t(1 + r) < z_- Q_t$$

It may however also happen that:

$$L_t \frac{1 + r}{1 - p} > z_- Q_t$$

In that case the country could be safe if priced accordingly, and unsafe if priced at the risk-adjusted interest rate. As noted by Chamon (2007, p. 237, footnote 7), however, this risk can readily be avoided if the country directly negotiates with its creditors the amount D_{t+1} due tomorrow rather than the amount L_t raised today at a (given) interest rate. Indeed in that case, it can just select the amount which is on the right side of the curve.

Following Cohen and Portes (2004) we can also make another observation. Assume that lenders and borrowers are capable of a settlement *ex post*. When the debt has become unsustainable, this amounts to say that lenders are capable of extracting from the country a lower payment than due, the level that would make the country indifferent between defaulting and paying the lower amount asked by the lenders. Call V_t^- the corresponding amount: it measures the market value of paying $R_t = \lambda Q_t$ on every period after the shock has occurred. When the level of debt exceeds the threshold of solvency, the zero profit condition set by the lenders now amounts to:

$$L_t(1 + r) = (1 - p)D_{t+1} + pV_{t+1}^- \tag{8}$$

In that case one can now see that:

$$D_{t+1} > V_{t+1}^- \Rightarrow L_t(1 + r) > V_{t+1}^-$$

Contrary to the case of outright default one then sees that if a country is threatened by default at a risk-adjusted interest rate, it would also have been threatened at the riskless rate.

The intuition is simple: for a given set of fundamentals there can only be one equilibrium, in the simplest settings at least. What drives the multiple equilibrium case is the fact that the crisis endogenously destroys part of the fundamentals upon which the debt is repaid (since after default, in the earlier case, creditors receive nothing). This may be the key reason why corporate self-fulfilling debt crises are a curiosity. To the extent that an appropriate bankruptcy procedure exists, the risk that a financial crisis can endanger, out of its own making, the value of a firm is much reduced.

This result leads us to stick to the simpler interpretation of multiple equilibria that we suggested earlier, based on the *ex post* cost of a debt crisis arising from the two potential values of γ.

A self-fulfilling equilibrium may take place when:

$$\frac{\lambda(1 - \gamma)}{r - g + p} < z_t < \frac{\lambda(1 - \gamma_1)}{r - g + p}$$

In such range indeed a country may become risky (and later on insolvent in case of a bad shock) by the sheer effect of the fear of the debt crisis itself, to the extent that the crisis has the potential to destroy endogenously the fundamentals upon which the debt is repaid. In that case the country pays a risk premium, and under the potential realization of a bad shock, suffers a capital flight/exchange rate crisis that self-fulfillingly imposes default.

Following the interesting insight of Cole and Kehoe (2000), we can note however that a country within the multiple equilibrium zone may want to escape it, and resist the Panglossian behavior, at least up to a certain value of debt. A country may indeed want to reduce its exposure to risk below the optimum level implied by the Euler equation in order to avoid the multiple equilibrium risk. The range of self-enforcing behavior is consequently shrinked from the danger zone $[z_-, z_+]$ down to a narrower interval. Past a new threshold however, the country acts as before in a Panglossian way.

3.5 A typology

Let us restrict ourselves to cases where a debtor has access and is willing to enter the market of risky debt. This will happen when the country is not too risky (when p is not too large in the model) or when growth and recession are not too large (γ and g are each small). A debtor may then find itself in one of the following situation:

1. It may behave very prudently, keeping its debt low enough to avoid the risk of a debt crisis, even in the event of a bad shock.

2. Passed a threshold of debt, the same debtor may instead "self-enforcingly" build up debt to its upper limit, taking a risk of default of probability p, ignoring in a Panglossian way the consequences of adverse shocks.

3. Debt crises may be driven by exogenous shocks, which have the potential to reduce the ability of the country to service its debt.

4. Debt crises may be driven by the financial markets themselves. A self-fulfilling crisis such as we defined it is then an episode where it is the financial crisis that causes output to fall rather than the other way round.

It is such typology that we now try to bring to the data.

4 Dataset

4.1 Debt crises

Our empirical strategy relies on a dataset of distress and normal times episodes, following the methodology of Kraay and Nehru (2004).

More precisely, for a given year, a country is considered to be in debt crisis if at least one of the following three conditions holds:

1. The country receives debt relief from the Paris Club, in the form of a rescheduling and/or a debt reduction.

2. The sum of its principal and interest arrears is large relatively to the outstanding debt stock.

3. The country receives substantial balance of payments support from the IMF through a non-concessionnal Standby Arrangement (SBA) or Extended Fund Facility (EFF).

We choose the same thresholds than Kraay and Nehru (2004) for the last two conditions, that is a country is considered to be in crisis if its arrears are above 5% of the total stock of its outstanding debt, or if the total amount agreed under SBA/EFF is above 50% of the country's IMF quota. Moreover, a country receiving Paris Club relief for a given year is also considered to be in crisis for the following two years, since the relief decision is typically based on three-year balance of payments projections by the IMF.

Having defined when a country is considered to be in crisis or not, we then define debt distress episodes as periods of at least three consecutive years of crisis. Moreover, we impose the restriction that a distress episode should be preceded by at least three years without crisis, so that we can consider macroeconomic variables before a crisis episode as being exogenous to the crisis.

We also define normal times episodes as five consecutive years without any crisis (without imposing any other restriction).

For identifying debt distress and normal times episodes, we use the following data sources:

- the World Bank's *Global Development Finance 2006* for data on debt levels and payment arrears,

- the Paris Club website[2] for information on debt reliefs,

- the IMF's *International Financial Statistics 2006* for data on SBA/EFF commitments.

In our subsequent econometric estimations, we also use two other sources:

[2] http://www.clubdeparis.org

- the World Bank's *World Development Indicators 2006* for general macroeconomic variables,
- the *Penn Word Tables* (version 6.2) for data on Purchasing Power Parity (PPP) variables.

The set of countries over which are made the computations consists of the 135 developing countries defined by the World Bank, from which we removed the 38 countries which have absolutely no access to private financial markets[3].

We choose to remove them since their indebtedness situation is somewhat different from that of the rest of the developing world (in particular, they have a much higher proportion of concessional lending); from the standpoint of the model, they probably fall into the category of those who have no access to risky markets (*i.e.* when condition (2) does not hold), and their debt dynamics must consequently be different.

We are therefore left with a sample of 97 countries. From the time angle, our data cover the period 1970-2004.

Prior to the elimination of certain observations in our econometric estimations (due to missing data), our largest sample of episodes consists of 70 distress episodes, and 223 normal times episodes.

To summarize, the differences between our dataset and that of Kraay and Nehru are twofold: first, we update their data up to 2004, which is relatively minor but allows to include for instance the Ecuadorian debt crisis of 2000. Second, we restrict our analysis to the countries which are emerging countries having access to private credit markets.

4.2 Currency crises

In addition to debt crises, we also study currency crises, which we define in the same way than Frankel and Rose (1996).

For a given year, a country is said to undergo a currency crisis if the two following conditions hold:

1. The exchange rate (against the US dollar) has fallen of more than 25% since the previous year.

[3] We define market access as in Gelos et al. (2004). The countries which we removed are those which never accessed to international credit markets between 1980 and 2000, according to the authors' definition. The complete country list can be found at page 29 of their paper.

2. This rate of depreciation of the exchange rate must be at least 10% greater than that of the previous year.

The second condition is specifically designed for countries constantly experiencing high inflation rates: were we to require only the first condition, these countries would be constantly considered as undergoing a currency crisis.

Over our sample of 97 countries and 35 years, we find 401 occurences of currency crisis, which gives a crisis probability of 11.8%[4]. Among all these occurences of crisis, 30 show up before a debt crisis (that is, during the three years immediately preceding a debt crisis), and 162 show up during a debt crisis episode (as defined above). Therefore, 7.5% of currency crises can be roughly considered as preceding a debt crisis, and 40.4% as coexisting with or immediately following a debt crisis. The remaining 52.1% seem, at first glance, to be unrelated to debt crises.

5 Econometric model

5.1 Core equations

Our empirical framework is given by the following system of two simultaneous equations:

$$d_{it} = X_{i,t-1}\beta_X + c_{it}\, Y_{i,t-1}\beta_Y + u_{it} \tag{9}$$

$$c_{it} = \mathbf{1}_{\{\alpha\, d_{it} + Z_{i,t-1}\beta_Z + v_{it} > 0\}} \tag{10}$$

where i indexes countries, t indexes time, d_{it} is debt-to-GDP ratio, c_{it} is a dummy indicating a debt crisis, α is a scalar parameter, $X_{i,t-1}$, $Y_{i,t-1}$ and $Z_{i,t-1}$ are row-vectors of exogenous variables, β_X, β_Y and β_Z are column-vectors of parameters, and u_{it} and v_{it} are stochastic exogenous shocks.

We assume the following normal distribution for shocks (which are supposed to be independent and identically distributed over periods and countries):

$$\begin{pmatrix} u_{it} \\ v_{it} \end{pmatrix} \rightsquigarrow \mathcal{N}\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_u^2 & 0 \\ 0 & 1 \end{pmatrix}\right)$$

The crisis dummy is therefore defined by a probit-like equation. Identifiability is guaranteed by setting the variance of v_{it} to unity.

[4]This is actually an underestimate because of the many missing observations, in particular for the relatively recent CIS countries.

5.2 Multiple equilibria

Since d_{it} and c_{it} appear in both equations, our model is not well-specified at this stage. Indeed, for a given set of exogenous $X_{i,t-1}$, $Y_{i,t-1}$, $Z_{i,t-1}$, and for a given draw of the random variables u_{it} and v_{it}, the model doesn't rule out the possibility of having two pairs (d_{it}, c_{it}) satisfying equations (9) and (10): of those two pairs, one would be a no-crisis scenario ($c_{it} = 0$), and the other a crisis scenario ($c_{it} = 1$).

This feature is precisely the possibility of multiple equilibria that we are trying to modelize. Let us now present the extensions to the model that make it well-specified.

Let us define the following notations:

$$d_{it}^0 = X_{i,t-1}\beta_X + u_{it}$$

$$d_{it}^1 = X_{i,t-1}\beta_X + Y_{i,t-1}\beta_Y + u_{it} = d_{it}^0 + Y_{i,t-1}\beta_Y$$

In words, d_{it}^0 is the level of debt-to-GDP ratio that would be reached if no crisis occurrred ($c_{it} = 0$). Conversely, d_{it}^1 is the level of debt-to-GDP ratio that would be reached if a crisis occurred ($c_{it} = 1$).

With these notations, a solution to equations (9) and (10) is necessarily $(d_{it}^0, 0)$ or $(d_{it}^1, 1)$.

The first assumption that we make over the parameters of the model is the following:

$$\forall i, t: \; Y_{i,t-1}\beta_Y > 0 \tag{11}$$

This constraint implies that $d_{it}^0 < d_{it}^1$: the debt-to-GDP ratio is always worse in a crisis scenario than in a no-crisis scenario, *ceteris paribus*.

The second assumption is:

$$\alpha > 0 \tag{12}$$

This simply states that the probability of a debt crisis (as given by equation (10)) is an increasing function of the debt-to-GDP ratio.

Finally, we introduce a third random variable δ_{it} following a Bernouilli distribution of parameter p (that is: $\mathbb{P}(\delta_{it} = 1) = p$ and $\mathbb{P}(\delta_{it} = 0) = 1 - p$). The variable δ_{it} is a sunspot: its role is to discriminate between the two equilibria when both are possible.

Given these extensions, we are now able to describe how the model behaves. For a given set of exogenous $X_{i,t-1}$, $Y_{i,t-1}$, $Z_{i,t-1}$, and for a given draw of random variables u_{it}, v_{it}, and δ_{it}, three cases are possible:

- If $\alpha\, d_{it}^0 + Z_{i,t-1}\beta_Z + v_{it} > 0$, a no-crisis equilibrium is impossible. And because of equations (11) and (12), we have $\alpha\, d_{it}^1 + Z_{i,t-1}\beta_Z + v_{it} > 0$. This is the crisis equilibrium inexorably driven by economic fundamentals.

- If $\alpha\, d^1_{it} + Z_{i,t-1}\beta_Z + v_{it} < 0$, a crisis equilibrium is impossible. And because of equations (11) and (12), we have $\alpha\, d^0_{it} + Z_{i,t-1}\beta_Z + v_{it} < 0$. This is the no-crisis equilibrium.

- If $\alpha\, d^1_{it} + Z_{i,t-1}\beta_Z + v_{it} > 0 > \alpha\, d^0_{it} + Z_{i,t-1}\beta_Z + v_{it}$, we are in the multiple equilibria case mentionned above. Both equilibria are possible. The outcome is given by the sunspot: $c_{it} = \delta_{it}$ (and d_{it} is set accordingly). If $\delta_{it} = 1$, the crisis is of a self-fullfilling nature: it could have been avoided (if the sunspot had been different), since the fundamentals are compatible with a no-crisis equilibrium.

The derivation of the likelihood function of the model can be found in appendix C.

5.3 Prudent versus Panglossian countries

Since our theoretical model predicts that some countries will adopt a prudent behavior, while others will accumulate debt, ignoring the risk of a crisis in a Panglossian way, we want to distinguish these two categories in the data.

Our strategy relies on a simple probit estimation: using our dataset of episodes, we estimate the probability of a debt crisis as a function of several exogenous variables[5]. This enables us to compute the probability of a debt crisis predicted by the model, independently of the actual realization or not of a crisis.

Tables 5, 6 and 7 (in appendix D) give the result of this computation for our set of countries, along with the indication of whether they had a crisis during our time period 1970-2004.

We consider this predicted crisis probability as a good proxy for the degree to which a given country is prudent[6]. We therefore classify as prudent the countries which have a mean predicted crisis probability below a certain threshold (to be defined below), and as Panglossian the others[7].

[5] Those variables are: debt-to-GDP ratio, log of per capita real PPP GDP, total debt service to exports ratio, overvaluation of exchange rate (measured by US$ GDP to PPP GDP ratio). All exogenous are taken two years before the beginning of the episode. The methodology is exactly that of Kraay and Nehru (2004), using a slightly different set of exogenous variables.

[6] A rougher criterion would have been to consider as Panglossian all countries having experienced a crisis during the sample period, and as prudent all the others, but this is not very satisfactory. Indeed a prudent country may have been unlucky one year and have experienced a crisis, or conversely a Panglossian country may have been lucky for a long period of time and escaped the risk of crisis.

[7] Due to missing data, it is impossible to compute the probability for a few countries.

6 Results

6.1 Baseline specification

The model is estimated over the debt crises episodes dateset presented in section 4.1. Details about the estimation procedure can be found in appendix E.

Column (1) of tables 1 and 2 reports the results for our baseline specification. All exogenous variables are taken in $t-2$ (*i.e.* two years before the beginning of the episode). The parameter p is here calibrated to 1, which reflects the assumption that, when two equilibria are possible, the market always chooses the worst one (we return below on this assumption).

The threshold predicted crisis probability used to separate prudent from Panglossian countries (as defined in section 5.3) is set at 20% (remember that we take the time interval of tranquil times to be 5 years). Among the values which we have tested (15%, 20%, 25%, 30%, 35%), it is the one which maximises the likelihood of the different estimations. This corresponds to an annual risk of 4.45%, or in terms of a spread over riskless rate, to a threshold of 445 basis points.

The upper part of the tables report the debt-to-GDP ratio dynamics in the absence of a crisis. Some variables are included to reflect the "accounting" dimension of the dynamics: growth and real depreciation of the currency have an automatic impact on the value of the GDP expressed in US$.

More precisely, if Q_t is GDP in (current) US$ and Q_t^* is GDP in (current) local currency unit (LCU), one has $Q_t^* = E_t Q_t$ where E_t is the nominal exchange rate expressed in LCU per US$. Moreover, one has: $Q_t^* = (1 + g_{t/t-1})(1+\pi_{t/t-1})Q_{t-1}^*$ where $g_{t/t-1}$ is growth rate and $\pi_{t/t-1}$ is inflation rate (both between $t-1$ and t). This leads to: $Q_t = \frac{1+g_{t/t-1}}{1+\delta_{t/t-1}} Q_{t-1}$ where $\delta_{t/t-1} = \frac{E_t}{(1+\pi_{t/t-1})E_{t-1}} - 1$ is the real exchange rate depreciation rate (omitting US inflation).

Using a first-order approximation, and assuming that nominal liabilities are constant, this gives:

$$\frac{D}{Q_t} = (1 - g_{t/t-1} + \delta_{t/t-1}) \frac{D}{Q_{t-1}}$$

which is the rationale behind introducing $\frac{D}{Q}$, $g\frac{D}{Q}$ and $\delta\frac{D}{Q}$ in the debt dynamics. One can observe that the coefficients obtained for these variables are

We choose to classify them as prudent if they never experienced a crisis, and as Panglossian if they did.

Table 1: Baseline specification

	(1)	(2)	(3)	(4)
Debt/GDP ratio dynamics (in the absence of a crisis) (equation (9))				
β_X: Debt/GDP (t-2)	0.979***	0.971***	0.955***	0.976***
	(0.048)	(0.047)	(0.047)	(0.042)
β_X: Debt/GDP * Growth (t-1/t-2)	-1.847***	-1.832***	-1.864***	-1.774***
	(0.347)	(0.340)	(0.344)	(0.339)
β_X: Debt/GDP * Real depreciation (t-1/t-2)	1.145***	1.278***	1.394***	1.281***
	(0.162)	(0.164)	(0.159)	(0.160)
β_X: Debt/GDP * Growth fall (t-2)	0.077*	-0.076	-0.062	-0.071
	(0.035)	(0.055)	(0.056)	(0.055)
β_X: Debt/GDP * Growth fall * Panglossian (t-2)		0.212***	0.226***	0.206***
		(0.060)	(0.060)	(0.060)
β_X: Constant	0.061***	0.067***	0.074***	0.065***
	(0.014)	(0.014)	(0.013)	(0.013)
σ_u	0.106***	0.104***	0.106***	0.104***
	(0.005)	(0.005)	(0.005)	(0.005)
Debt/GDP ratio dynamics (malus in case of crisis) (equation (9))				
β_Y: Debt/GDP (t-2)	0.004	0.020	0.145***	
	(0.069)	(0.068)	(0.038)	
β_Y: Debt/GDP * US$ GDP / PPP GDP (t-2)	0.409**	0.335*		0.371***
	(0.151)	(0.149)		(0.081)
β_Y: Constant				
Debt crisis determinants (equation (10))				
α: Debt/GDP (t)	2.409***	2.403***	2.622***	2.462***
	(0.432)	(0.432)	(0.454)	(0.435)
β_Z: Log per capita PPP real GDP (t-2)	-0.349**	-0.328**	-0.367**	-0.338**
	(0.127)	(0.127)	(0.129)	(0.127)
β_Z: US$ GDP / PPP GDP (t-2)	1.078*	1.173*	1.553**	1.249*
	(0.525)	(0.526)	(0.528)	(0.522)
β_Z: Total Debt Service / Exports (t-2)				
β_Z: Constant	0.478	0.275	0.320	0.291
	(1.035)	(1.036)	(1.054)	(1.041)
p: Sunspot Bernouilli parameter	1.000	1.000	1.000	1.000
Self-fulfilling probability	0.180	0.164	0.151	0.162
Number of observations	251	251	251	251
Log-likelihood	94.435	100.498	98.124	100.498
AIC	-164.870	-174.995	-172.248	-176.996

Table 2: Baseline specification (continued)

	(5)	(6)	(7)
Debt/GDP ratio dynamics (in the absence of a crisis) (equation (9))			
β_X: Debt/GDP (t-2)	1.014***	0.955***	0.959***
	(0.041)	(0.048)	(0.047)
β_X: Debt/GDP * Growth (t-1/t-2)	-1.952***	-1.879***	-1.736***
	(0.346)	(0.343)	(0.339)
β_X: Debt/GDP * Real depreciation (t-1/t-2)	1.379***	1.371***	1.269***
	(0.161)	(0.159)	(0.165)
β_X: Debt/GDP * Growth fall (t-2)	-0.075	-0.055	-0.109
	(0.056)	(0.056)	(0.058)
β_X: Debt/GDP * Growth fall * Panglossian (t-2)	0.242***	0.223***	0.245***
	(0.060)	(0.060)	(0.064)
β_X: Constant	0.057***	0.074***	0.069***
	(0.013)	(0.015)	(0.014)
σ_u	0.107***	0.105***	0.104***
	(0.005)	(0.005)	(0.005)
Debt/GDP ratio dynamics (malus in case of crisis) (equation (9))			
β_Y: Debt/GDP (t-2)		0.132*	0.021
		(0.064)	(0.068)
β_Y: Debt/GDP * US$ GDP / PPP GDP (t-2)			0.360*
			(0.153)
β_Y: Constant	0.059**	0.008	
	(0.019)	(0.032)	
Debt crisis determinants (equation (10))			
α: Debt/GDP (t)	2.756***	2.574***	2.118***
	(0.486)	(0.452)	(0.456)
β_Z: Log per capita PPP real GDP (t-2)	-0.340**	-0.320*	-0.488***
	(0.129)	(0.128)	(0.142)
β_Z: US$ GDP / PPP GDP (t-2)	1.390**	1.385**	1.467**
	(0.528)	(0.530)	(0.544)
β_Z: Total Debt Service / Exports (t-2)			2.744***
			(0.737)
β_Z: Constant	0.104	0.031	0.963
	(1.049)	(1.048)	(1.115)
p: Sunspot Bernouilli parameter	1.000	1.000	1.000
Self-fulfilling probability	0.154	0.156	0.136
Number of observations	251	251	249
Log-likelihood	95.989	98.086	110.178
AIC	-167.978	-170.172	-192.356

consistent with the accounting dynamics: the estimated parameter for $g\frac{D}{Q}$ is near 2 (and not 1) because of the two years lag[8].

6.2 Prudent versus Panglossian dynamics

The partial accounting identity between growth rates and the dynamics of the debt-to-GDP ratio relies on the fact that debt is a stock that is slow to move. After some time however, a country can act to restore or to achieve equilibrium targets for its debt-to-GDP ratio. This is where the difference between prudent and Panglossian countries steps in. In response to a bad shock, a prudent country will attempt to cancel its impact on its solvency by implementing appropriate policies and restore earlier ratios. A Panglossian country instead will ignore the bad shock and let its risk drift.

In order to test for this mechanism, we have measured the extent to which prudent and Panglossian countries tend to react to a bad shock in the spell of a three years time horizon. In order to do so, we constructed a variable "growth fall", which is a dummy capturing abrupt slowdowns of economic growth, as modelized by the bad shocks in the theoretical part. Technically, the dummy equals one if growth rate in $t-2$ is below 66% of moving average of growth rates between $t-7$ and $t-3$. One can see that the interaction of debt-to-GDP with "growth fall" is statistically signifiant in model (1), which means that when a bad shock occurs, countries let their debt-to-GDP ratio be augmented, three years after the facts, by 7% on average[9].

However, in model (2), we add the interaction of this variable with the dummy corresponding to "Panglossian" countries (as defined in section 5.3). It appears that the previous effect is entirely driven by Panglossian countries: when a bad shock occurs, Panglossian countries will not correct for the bad shock on the denominator of their debt-to-GDP ratios, which is augmented by 20% on average. On the contrary, prudent countries tend to stablize, in less than three years, their debt-to-GDP ratio to earlier values. These effects are clearly consistent with our theoretical model which predicts that high debt countries ignore bad shocks while low debt countries try to stabilize their debt to a prior level in response to a bad shock, and only fail to do so

[8] Exogenous variables are lagged two periods, while growth and real depreciation are only computed between $t-2$ and $t-1$ (instead of t). For both variables, the corresponding coefficients are greater than one in absolute value, which reflects the fact that there is high positive correlation between $g_{t/t-1}$ and $g_{t-1/t-2}$, and positive though lower correlation between $\delta_{t/t-1}$ and $\delta_{t-1/t-2}$.

[9] Note that this effect is independent of the automatic accounting effet of low growth, since the variable "growth fall" is constructed using growth rate between $t-3$ and $t-2$, which is already incorporated in debt-to-GDP ratio of period $t-2$.

if hit by successive bad shocks.

Acrross the different specifications, we explore several ways of explaining the deterioration of the debt-to-GDP in case of crisis. It is interesting to note that the US$-GDP-to-PPP-GDP ratio appears as one of those determinants (see models (1), (2), (4) and (7)): it reflects the fact that an overvaluation of the local currency is associated with a higher risk of currency crisis, which – when triggered – translates into a smaller GDP expressed in terms of current US dollars.

The fact that a currency crisis can be the channel through which a self-fulfilling crisis is triggered is perfectly in line with our theoretical model: the loss of confidence in the solvability of the country can trigger a currency crisis, which in itself has a direct effect on the solvency of the country (since its external debt is denominated in US dollars).

Our estimators for the determinants of debt crises are also consistent: debt crises are made more likely by high *current* debt-to-GDP ratio, low real income level, overvaluation of local currency, and high debt service ratio.

Beside the results of parameters estimations, the tables also report information about the percentage of crises which were of a self-fulfilling nature. Indeed, with our model, it is possible, for a given crisis, to compute the *a posteriori* probability that it was of a self-fulfilling nature, by opposition to a crisis solely driven by fundamentals and exogenous shocks (see below section 6.4). The line entitled "Self-fulfilling probability" in the tables reports the mean of that probability over all the crises of the dataset.

Since, in tables 1 and 2, the figures of that line are comprised between 13.6% and 18.0%, one can conclude that self-fulfilling crises are around 15% of all the crises included in our dataset.

It should here be recalled that this figure is highly dependent on the parameter p, which is the probability that the market chooses the crisis equilibrium when the good equilibrium is also possible. The figure of 15% is obtained when p is calibrated to 1, that is when the markets are considered as "panic prone" (*i.e.* they always choose the bad equilibrium when it is possible).

6.3 Alternative specification

We have tried to estimate the parameter p, but it is always statistically insignificant, and the result seems quite unstable, hence our choice to calibrate it to sensible values.

In tables 8 and 9 in appendix F, we report results when the parameter p is calibrated to 0.5. This means that, when there is a possibility of self-fulfilling crisis, it is realized half of the time. The results are basically the same than in the baseline, except that the proportion of self-fulfilling crises is halved, here comprised between 6.4% and 9.9%.

6.4 *A posteriori* self-fulfilling probabilities

In tables 3 and 4, we report, for each crisis of the sample, the *a posteriori* probability that it was a self-fulfilling one. These probabilities are computed as the measure of the set of events where the (unobservable) trigger of default v_{it} is such that $\alpha\, d^1_{it} + Z_{i,t-1}\beta_Z + v_{it} > 0 > \alpha\, d^0_{it} + Z_{i,t-1}\beta_Z + v_{it}$. Since we consider only episodes of crisis, the value of d^1_{it} is directly observable, and that of d^0_{it} can be easily deduced by substracting $Y_{i,t-1}\beta_Y$. The probability is then straightforward to compute since v_{it} is assumed to be normally distributed[10]..

The crises are ordered by their likelihood of being self-fulfilling ones. The figures given are computed from the means of those computed for models (2), (3) and (4) of the baseline specification.

In words, the Jordan crisis of 1989 or the Rwandan crisis of 1994 were almost surely not created by a self-fulfilling process. They could not have been avoided by only restoring confidence.

On the contrary, the crises of Jamaica in 1977, Venezuela in 1989 or Argentina in 1983 may be self-fulfilling ones. There is almost one chance in third that they could have been avoided if confidence had been maintained and panic avoided.

[10]See equation (13) in appendix C.

Table 3: Individual crises self-fulfilling probabilities

Country	Year	Crisis length	Self-fulfill prob. (in %)
Jordan	1989	16	1.5
Rwanda	1994	11	2.1
Somalia	1981	24	2.2
Nigeria	1986	19	5.6
Congo, Rep.	1985	20	5.6
Guinea-Bissau	1981	23	7
India	1981	3	7.5
Madagascar	1980	25	7.7
Benin	1970	9	8.6
Turkey	1978	7	9.7
Cote d'Ivoire	1981	16	9.9
Egypt, Arab Rep.	1977	4	10.1
Congo, Dem. Rep.	1976	29	10.2
Uruguay	1983	4	10.5
Ethiopia	1991	14	10.8
Benin	1983	16	11.1
Bangladesh	1979	3	11.5
Philippines	1976	3	12.3
Solomon Islands	2002	3	12.7
Ghana	1970	7	13.5
Kyrgyz Republic	2002	3	14.1
Paraguay	1986	9	14.5
Pakistan	1972	5	14.5
Uruguay	2002	3	14.7
Chile	1983	7	15
Kenya	1975	3	15.8
Comoros	1987	18	16.3
Gabon	1986	19	16.5
Egypt, Arab Rep.	1984	12	16.5
Mexico	1983	10	16.7
Peru	1977	4	16.8

Table 4: Individual crises self-fulfilling probabilities (continued)

Country	Year	Crisis length	Self-fulfill prob. (in %)
Kenya	1992	5	17
Pakistan	1994	10	17
Senegal	1980	23	17.3
Indonesia	1970	3	17.3
Ghana	1996	3	17.6
Panama	1978	3	17.6
Sudan	1977	28	17.9
Brazil	1983	3	17.9
Tunisia	1986	6	18.1
Niger	1983	22	18.3
Colombia	1999	3	18.5
Kenya	2000	3	18.6
Brazil	1998	7	18.6
Pakistan	1980	4	18.8
Ecuador	2000	5	19.3
Dominican Republic	1983	17	19.3
Honduras	1979	23	19.4
Cameroon	1987	18	20.9
El Salvador	1990	3	21.2
Algeria	1994	4	21.4
Indonesia	1997	8	21.4
Ecuador	1983	14	22
Turkey	1999	6	22.7
Thailand	1997	3	22.9
Chile	1972	5	23
Costa Rica	1980	16	24.1
Trinidad and Tobago	1988	5	24.2
Morocco	1980	15	24.4
Argentina	1983	13	27.1
Venezuela, RB	1989	4	28.7
Jamaica	1977	24	30.7

7 Conclusion

We have tried to distinguish two attitudes towards debt. The attitude of prudent borrowers, which attempt to stabilize their debts, even in the event of a bad shock, to low levels, and Panglossian borrowers, which only take account of the best scenarios, and rationally anticipate to default on their debt when hit by a bad (or a sequence of bad) shock(s). We have shown empirically that this distinction is consistent with the data. Past a threshold of risk, countries fail to respond to bad shocks and let their risk drift accordingly. Interpreted in terms of annual risk, this threshold corresponds to a risk worth spread of about 450 basis points over the riskless rate.

We also have distinguished two types of debt crises. Those which are the effect of an exogenous shock, and those which are self-fulfillingly created by the financial markets themselves. We have shown that the large majority of crises are of the first kind, although the probability of self-fulfilling cases is not negligible.

These results have a few policy implications that we leave to future work. For one thing, if the earthquake model is the right one, then there is room for improving the stability of financial markets by allowing more state contingent debt. It indeed remains a question to understand why sovereign debt contains so few contingency clauses.

Regarding the self-fulfilling case, the now old debate on sovereign debt restructuring remains important, albeit relatively less important, if one trusts our results, than finding more innovative source of finances.

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A Debt limits

Consider the situation of a country which has reached the upper limit of debt, in the sense that it is indifferent between servicing the debt and defaulting:

$$J(D_t, Q_t) = J_d(Q_t)$$

We make the hypothesis that in this situation, and assuming repayment, the optimal strategy is to choose a debt D_{t+1} which would be repaid in case of a good shock in $t+1$, but would be defaulted on in case of a bad shock.

Call C_t^* the corresponding current level of consumption. One can write:

$$J(D_t, Q_t) = u(C_t^*) + \beta(1-p)J[D_{t+1}, (1+g)Q_t] + \beta p\, J_d[(1-\gamma)Q_t]$$

Using the analysis of section 3.2, and under condition (3), it is easy to show that the optimal choice would be $D_{t+1} > (1+g)D_t$. However, investors will not allow this, since the country would then default even in the good state of nature in $t+1$. Being rationed, the country sets: $D_{t+1} = (1+g)D_t$. It follows that $J[D_{t+1}, (1+g)Q_t] = J_d[(1+g)Q_t]$, since the problem is homothetic.

Then, using the characterization of J_d:

$$J_d(Q_t) = u[(1-\lambda)Q_t] + \beta(1-p)J_d[(1+g)Q_t] + \beta p\, J_d[(1-\gamma)Q_t]$$

one sees that $J(D_t, Q_t) = J_d(Q_t)$ and $J[D_{t+1}, (1+g)Q_t] = J_d[(1+g)Q_t]$ imply that $C_t^* = (1-\lambda)Q_t$. In other words, when a country has reached the default limit, the maximum that it is willing to pay is simply λQ_t.

Then, combining this with:

$$D_{t+1} = (1+\varrho)(D_t - Q_t + C_t^*)$$

and $D_{t+1} = (1+g)D_t$, one gets (after a first order approximation):

$$d_+ = \frac{D_t}{Q_t} = \frac{\lambda}{r-g+p}$$

One can then correspondingly define, as in the text, the two z thresholds, z_- and z_+ which assess the risk one period ahead.

The proof clearly says nothing of the fact that a country will indeed be willing to take the risk of default in the event of a bad shock. We have shown that: *if* the country is willing to take such risk, d_+ is the relevant threshold, and the analysis then proceeds as explained in section 3.2. But it may happen that a country is never willing to take such risk, as explained in section 3.1, and the threshold would then be different.

B Debt and exchange rates crises

The following tabulations give the complete list of the crisis episodes identified along the methodology of section 4.1.

For each crisis episode, the first three columns give the country, the year of the crisis outbreak, and the number of years it lasted. The columns labelled "type of crisis" give some precisions about the type of debt crisis, whether it was characterized by a Paris Club relief, accumulated arrears or IMF intervention (or several of these options). The table also shows if the debt crisis was accompanied by a currency crisis, whether before (during any of the three preceding years) or during the crisis episode.

The remaining columns give several macroeconomic indicators about the country: the debt-to-GDP ratio at three points in time (3 years before the outbreak, the year of the outbreak and three years later), the debt-to-PPP-GDP ratio (at the same dates), the debt-service-to-exports ratio, the annual rate of depreciation of the nominal exchange rate (before and after the crisis), the mean annual growth before the crisis and the mean effective interest rate charged on the debt before the crisis.

Country	Year	Length	Type of crisis			Currency crisis			D/GDP		
			Paris Club	Arrears	SBA/EFF	Before	During	Any	t-3	t	t+3
Indonesia	1970	3	Y	N	N	NA	N	NA	46.9	46.9	42.3
Benin	1970	9	N	Y	N	N	N	N	12.5	12.5	11.7
Ghana	1970	7	N	Y	N	N	Y	Y	25.8	25.8	30.6
Guinea	1970	35	Y	Y	Y	N	Y	Y	NA	NA	NA
Chile	1972	5	Y	Y	Y	Y	Y	Y	33.1	30.7	76.4
Pakistan	1972	5	Y	N	N	N	Y	Y	34.0	43.7	50.7
Tanzania	1972	33	Y	Y	Y	N	Y	Y	NA	NA	NA
Kenya	1975	3	N	N	Y	N	N	N	27.6	39.6	41.0
Congo, Dem. Rep.	1976	29	Y	Y	Y	N	Y	Y	13.2	30.2	30.0
Philippines	1976	3	N	N	Y	N	N	N	27.4	35.3	48.3
Jamaica	1977	24	Y	Y	Y	N	Y	Y	60.4	51.7	71.4
Egypt, Arab Rep.	1977	4	N	N	Y	N	N	N	24.5	80.2	83.5
Peru	1977	4	Y	N	Y	Y	Y	Y	38.8	64.4	45.4
Sudan	1977	28	Y	Y	Y	N	Y	Y	28.9	35.1	68.0
Panama	1978	3	N	N	Y	N	N	N	50.4	93.8	77.7
Turkey	1978	7	Y	N	Y	N	Y	Y	10.9	22.3	28.9
Honduras	1979	23	Y	Y	Y	N	Y	Y	27.1	52.6	63.5
Bangladesh	1979	3	N	N	Y	Y	N	Y	19.8	19.5	28.0
Mauritius	1979	3	N	N	Y	NA	NA	NA	NA	NA	53.3
Costa Rica	1980	16	Y	Y	Y	N	Y	Y	42.9	56.8	133.1
Madagascar	1980	25	Y	Y	Y	N	Y	Y	33.1	30.6	57.9
Senegal	1980	23	Y	Y	Y	N	Y	Y	31.7	49.3	83.8
Morocco	1980	15	Y	Y	Y	N	Y	Y	50.8	51.7	93.5
Pakistan	1980	4	Y	N	Y	N	N	N	50.0	41.9	41.9

Country	Year	Length	Type of crisis			Currency crisis			D/GDP		
			Paris Club	Arrears	SBA/EFF	Before	During	Any	t-3	t	t+3
India	1981	3	N	N	Y	N	N	N	12.4	12.1	16.5
Romania	1981	5	Y	N	Y	NA	NA	NA	NA	NA	NA
Cote d'Ivoire	1981	16	Y	Y	Y	N	Y	Y	48.6	96.5	124.9
Guinea-Bissau	1981	23	Y	Y	N	N	Y	Y	43.9	97.8	183.1
Somalia	1981	24	Y	Y	Y	Y	Y	Y	91.8	151.0	190.0
Argentina	1983	13	Y	Y	Y	Y	Y	Y	35.3	44.2	47.3
Niger	1983	22	Y	Y	Y	Y	Y	Y	34.4	52.7	74.3
Benin	1983	16	Y	Y	N	Y	Y	Y	30.2	68.1	74.0
Brazil	1983	3	Y	N	Y	Y	Y	Y	30.4	48.5	40.7
Chile	1983	7	Y	N	Y	Y	Y	Y	43.8	90.7	119.3
Dominican Republic	1983	17	Y	Y	Y	N	Y	Y	30.2	34.0	60.2
Ecuador	1983	14	Y	Y	Y	N	N	N	50.4	67.9	90.5
Mexico	1983	10	Y	N	Y	Y	Y	Y	29.5	62.5	77.9
Uruguay	1983	4	N	N	Y	Y	Y	Y	16.4	64.8	66.7
Egypt, Arab Rep.	1984	12	Y	Y	Y	N	Y	Y	94.3	105.1	109.0
Congo, Rep.	1985	20	Y	Y	Y	N	Y	Y	91.8	141.2	184.9
Lebanon	1986	6	N	Y	N	NA	Y	Y	NA	NA	37.7
Sao Tome and Principe	1986	19	Y	Y	N	N	Y	Y	83.9	122.9	291.9
Gabon	1986	19	Y	Y	Y	N	Y	Y	27.0	57.1	80.0
Nigeria	1986	19	Y	Y	Y	Y	Y	Y	50.2	109.9	126.3
Paraguay	1986	9	N	Y	N	Y	Y	Y	25.2	58.9	54.6
Tunisia	1986	6	N	N	Y	N	N	N	48.6	65.9	69.0
Cameroon	1987	18	Y	Y	Y	N	Y	Y	37.2	37.9	59.7
Comoros	1987	18	N	Y	N	N	Y	Y	97.5	103.5	71.8

Country	Year	Length	Type of crisis			Currency crisis			D/GDP		
			Paris Club	Arrears	SBA/EFF	Before	During	Any	t-3	t	t+3
Trinidad and Tobago	1988	5	Y	Y	Y	Y	N	Y	19.6	46.7	46.7
Vietnam	1988	17	Y	Y	Y	Y	Y	Y	0.4	2.4	243.4
Jordan	1989	16	Y	Y	Y	N	Y	Y	78.2	177.2	150.0
Venezuela, RB	1989	4	N	N	Y	Y	Y	Y	58.3	76.8	64.7
El Salvador	1990	3	Y	N	N	N	N	N	50.2	44.8	29.3
Seychelles	1990	15	N	Y	N	N	N	N	69.4	49.7	38.7
Ethiopia	1991	14	Y	Y	N	N	Y	Y	99.9	95.8	181.7
Kenya	1992	5	Y	Y	N	N	Y	Y	71.2	83.9	80.8
Algeria	1994	4	Y	N	Y	Y	Y	Y	62.3	71.1	64.5
Rwanda	1994	11	Y	Y	N	Y	Y	Y	42.4	126.6	60.1
Pakistan	1994	10	Y	N	Y	N	N	N	51.4	52.8	48.2
Ghana	1996	3	Y	N	N	Y	Y	Y	76.7	83.6	83.3
Indonesia	1997	8	Y	Y	Y	N	Y	Y	61.0	63.1	87.5
Thailand	1997	3	N	N	Y	N	Y	Y	45.3	72.7	64.9
Brazil	1998	7	N	N	Y	N	Y	Y	22.8	30.7	45.5
Colombia	1999	3	N	N	Y	N	N	N	29.7	39.9	40.7
Turkey	1999	6	N	N	Y	Y	Y	Y	44.1	55.6	71.3
Kenya	2000	3	Y	N	N	N	N	N	49.3	48.4	45.6
Ecuador	2000	5	Y	N	Y	N	N	N	65.2	86.0	62.0
Kyrgyz Republic	2002	3	Y	N	N	Y	N	Y	139.0	115.3	NA
Solomon Islands	2002	3	N	Y	N	N	N	N	49.7	79.5	NA
Uruguay	2002	3	N	N	Y	N	Y	Y	35.3	86.4	NA

Country	Year	D/PPP-GDP			TDS/X	Exch. rate depreciation		Growth	Interest rate
		t-3	t	t+3		avg(t-3...t)	avg(t...t+3)	avg(t-3...t-1)	avg(t-3...t-1)
Indonesia	1970	16.0	16.0	16.0	13.0	29.7	4.3	6.9	1.0
Benin	1970	5.7	5.7	6.0	3.4	3.9	-7.4	2.6	1.0
Ghana	1970	12.6	12.6	13.4	10.8	5.4	11.0	3.2	2.1
Guinea	1970	14.6	14.6	22.8	NA	0.0	-5.9	NA	1.3
Chile	1972	17.2	17.5	27.6	27.3	29.4	182.1	4.9	3.5
Pakistan	1972	14.5	14.8	14.3	33.2	6.6	17.8	5.8	2.0
Tanzania	1972	8.6	49.4	63.7	NA	0.0	1.0	NA	0.9
Kenya	1975	12.0	21.3	23.6	8.6	0.9	1.7	9.0	3.5
Congo, Dem. Rep.	1976	9.8	28.9	26.0	9.2	15.3	26.0	2.1	3.4
Philippines	1976	7.3	11.2	16.9	22.5	3.2	-0.3	6.0	3.3
Jamaica	1977	43.8	41.8	43.2	37.2	0.0	22.4	-3.7	6.9
Egypt, Arab Rep.	1977	7.3	26.0	25.9	16.3	5.6	7.8	8.7	1.7
Peru	1977	19.7	27.0	18.6	42.5	25.8	41.2	4.9	5.0
Sudan	1977	18.7	29.2	46.1	12.7	0.0	17.3	14.6	1.8
Panama	1978	30.2	53.5	47.8	NA	0.0	0.0	1.5	4.4
Turkey	1978	9.2	19.3	18.2	19.1	17.5	52.6	7.0	5.6
Honduras	1979	13.2	28.1	33.4	29.1	0.0	0.0	10.3	5.1
Bangladesh	1979	5.0	5.4	6.7	28.8	0.7	9.1	5.1	1.9
Mauritius	1979	2.7	12.0	14.9	NA	NA	NA	NA	3.3
Costa Rica	1980	20.6	31.5	43.8	22.0	0.0	52.3	6.7	5.0
Madagascar	1980	18.4	24.3	32.2	37.7	-5.0	23.7	3.2	2.5
Senegal	1980	15.8	29.6	31.2	7.1	-5.0	19.7	0.1	3.8
Morocco	1980	24.6	29.6	30.6	19.1	-4.5	19.7	4.4	4.8
Pakistan	1980	14.8	12.7	10.6	31.9	0.0	8.3	5.3	2.5

Country	Year	D/PPP-GDP			TDS/X	Exch. rate depreciation		Growth	Interest rate
		t-3	t	t+3		avg(t-3...t)	avg(t...t+3)	avg(t-3...t-1)	avg(t-3...t-1)
India	1981	4.2	4.0	4.5	16.1	2.9	9.4	2.4	2.7
Romania	1981	1.9	13.5	7.8	NA	NA	NA	NA	4.3
Cote d'Ivoire	1981	37.6	62.3	47.5	16.4	6.2	15.8	0.8	6.5
Guinea-Bissau	1981	22.9	44.9	67.5	10.5	-1.7	34.5	-0.3	1.0
Somalia	1981	16.1	27.3	36.2	3.0	25.9	30.6	-1.0	0.3
Argentina	1983	15.9	23.7	24.6	107.4	101.6	148.3	-2.2	8.8
Niger	1983	23.4	19.0	26.9	22.9	19.7	-3.2	-0.0	9.2
Benin	1983	21.5	30.8	29.3	9.1	19.7	-3.2	6.3	3.0
Brazil	1983	15.2	18.9	15.1	69.4	79.8	105.5	1.8	12.1
Chile	1983	29.1	42.1	41.4	43.0	23.4	29.9	0.9	11.7
Dominican Republic	1983	15.6	15.9	17.6	29.8	0.0	35.5	3.9	9.1
Ecuador	1983	22.0	24.5	28.0	34.0	0.0	0.0	2.4	9.4
Mexico	1983	20.2	25.8	26.8	52.7	55.1	54.3	5.8	12.0
Uruguay	1983	12.3	24.4	23.7	19.6	44.5	49.4	-0.8	9.2
Egypt, Arab Rep.	1984	26.1	29.5	37.6	19.9	7.6	10.5	7.0	4.3
Congo, Rep.	1985	56.3	75.8	123.5	20.2	10.4	-13.7	12.1	5.7
Lebanon	1986	NA	NA	NA	NA	NA	85.4	NA	8.0
Sao Tome and Principe	1986	46.5	76.5	117.5	24.2	-3.1	39.1	NA	1.7
Gabon	1986	19.1	35.7	51.0	11.7	-3.2	-2.7	3.6	7.9
Nigeria	1986	37.5	42.2	36.9	53.8	26.4	32.0	-0.1	9.4
Paraguay	1986	12.8	16.3	14.1	13.7	42.2	23.8	1.3	4.0
Tunisia	1986	17.1	22.0	21.5	22.2	5.2	6.0	5.4	5.9
Cameroon	1987	15.4	21.0	28.1	15.9	-8.3	-2.0	7.4	6.2
Comoros	1987	20.4	34.0	26.9	28.9	-12.5	-3.3	2.8	1.2

Country	Year	D/PPP-GDP			TDS/X	Exch. rate depreciation		Growth	Interest rate
		t-3	t	t+3		avg(t-3…t)	avg(t…t+3)	avg(t-3…t-1)	avg(t-3…t-1)
Trinidad and Tobago	1988	13.8	23.9	24.0	11.0	15.0	3.3	-4.0	7.6
Vietnam	1988	NA	NA	28.2	NA	143.0	85.9	3.4	0.5
Jordan	1989	44.9	70.3	63.2	32.8	16.5	5.6	2.7	6.0
Venezuela, RB	1989	38.9	29.7	27.7	43.7	48.5	22.6	5.3	8.6
El Salvador	1990	14.7	14.2	10.5	34.6	0.0	0.0	1.8	3.9
Seychelles	1990	43.8	31.8	24.0	9.1	-1.6	-1.0	7.0	5.2
Ethiopia	1991	46.7	47.2	37.2	48.6	0.0	30.1	0.9	1.0
Kenya	1992	25.8	25.6	22.3	37.2	14.9	15.6	3.4	4.6
Algeria	1994	24.7	26.8	22.4	68.9	21.4	16.6	-0.5	7.1
Rwanda	1994	10.3	25.0	16.9	16.5	18.8	10.5	-1.6	1.3
Pakistan	1994	10.3	10.1	9.5	25.4	9.9	8.6	4.8	3.6
Ghana	1996	23.6	25.7	23.9	24.4	30.8	16.3	4.1	2.1
Indonesia	1997	16.9	16.5	17.1	30.4	9.9	35.4	7.9	5.0
Thailand	1997	18.4	26.3	19.7	14.0	7.4	8.2	8.0	4.3
Brazil	1998	15.1	20.7	18.0	39.7	7.8	23.6	3.4	6.2
Colombia	1999	13.5	15.2	13.0	36.6	17.6	11.8	2.0	6.4
Turkey	1999	25.0	28.1	33.6	28.0	54.7	42.6	5.9	5.7
Kenya	2000	17.7	16.0	16.7	22.1	8.7	-0.1	2.0	3.0
Ecuador	2000	29.3	24.6	26.7	31.2	0.0	0.0	-0.0	6.0
Kyrgyz Republic	2002	12.3	10.7	NA	20.9	6.2	NA	4.8	3.3
Solomon Islands	2002	15.5	20.5	NA	5.0	11.1	NA	-7.9	1.9
Uruguay	2002	20.7	34.3	NA	27.6	21.4	NA	-2.6	6.8

C Likelihood derivation

In this section we derive the likelihood $\mathcal{L}_\theta(d_{it}, c_{it}|X_{i,t-1}, Y_{i,t-1}, Z_{i,t-1})$ of a single observation (d_{it}, c_{it}) given the exogenous and the vector of parameters $\theta = (\beta_X, \beta_Y, \beta_Z, \alpha, \sigma_u, p)$.

For the remaining of this subsection, we drop the i and t subscripts for the sake of simplicity.

We note φ for the density function of the normal distribution (with zero mean and unity variance), and Φ for its cumulative distribution function.

C.1 Crisis case

If $c = 1$, we know that $d = d^1$. Then:

$$\mathcal{L}_\theta(d, 1|X, Y, Z) = \frac{1}{\sigma_u}\varphi\left(\frac{d - X\beta_X - Y\beta_Y}{\sigma_u}\right)\mathbb{P}(c = 1|d^1, X, Y, Z)$$

The last factor is:

$$\begin{aligned}\mathbb{P}(c = 1|d^1, X, Y, Z) \quad &= \quad \mathbb{P}(\alpha\, d^0 + Z\beta_Z + v > 0) + \\ &\quad\quad p\,\mathbb{P}(\alpha\, d^1 + Z\beta_Z + v > 0 > \alpha\, d^0 + Z\beta_Z + v)\end{aligned}$$

In the this equation, the first term corresponds to the crisis solely driven by fundamentals and exogenous shocks, and the second term to the self-fulfilling case.

It can be rewritten as:

$$\begin{aligned}\mathbb{P}(c = 1|d^1, X, Y, Z) \quad &= \quad \Phi[\alpha(d^1 - Y\beta_Y) + Z\beta_Z] + \\ &\quad\quad p\left\{\Phi(\alpha\, d^1 + Z\beta_Z) - \Phi[\alpha(d^1 - Y\beta_Y) + Z\beta_Z]\right\}\end{aligned}$$

For a given crisis observation, it is therefore possible to compute the *a posteriori* probability that the crisis is of a self-fulfilling nature (by opposition to a crisis solely driven by fundamentals and exogenous shocks). This probability is given by:

$$\tau(d^1, X, Y, Z) = \frac{p\,\{\Phi(\alpha\, d^1 + Z\beta_Z) - \Phi[\alpha(d^1 - Y\beta_Y) + Z\beta_Z]\}}{\mathbb{P}(c = 1|d^1, X, Y, Z)} \tag{13}$$

Finally, the complete likelihood is given by:

$$\begin{aligned}\mathcal{L}_\theta(d, 1|X, Y, Z) \quad &= \quad \frac{1}{\sigma_u}\varphi\left(\frac{d - X\beta_X - Y\beta_Y}{\sigma_u}\right)\left\{(1 - p)\,\Phi[\alpha(d - Y\beta_Y) + Z\beta_Z] + \right. \\ &\quad\quad \left. p\,\Phi(\alpha\, d + Z\beta_Z)\right\}\end{aligned}$$

C.2 No-crisis case

If $c = 0$, we know that $d = d^0$. Then:

$$\mathcal{L}_\theta(d, 0|X, Y, Z) = \frac{1}{\sigma_u}\varphi\left(\frac{d - X\beta_X}{\sigma_u}\right)\mathbb{P}(c = 0|d^0, X, Y, Z)$$

The last factor is:

$$\begin{aligned}\mathbb{P}(c = 0|d^0, X, Y, Z) &= \mathbb{P}(\alpha\, d^1 + Z\beta_Z + v < 0) + \\ &\quad (1-p)\,\mathbb{P}(\alpha\, d^1 + Z\beta_Z + v > 0 > \alpha\, d^0 + Z\beta_Z + v) \\ &= 1 - \Phi[\alpha(d^0 + Y\beta_Y) + Z\beta_Z] + \\ &\quad (1-p)\left\{\Phi[\alpha(d^0 + Y\beta_Y) + Z\beta_Z] - \Phi(\alpha\, d^0 + Z\beta_Z)\right\}\end{aligned}$$

The complete likelihood is therefore given by:

$$\begin{aligned}\mathcal{L}_\theta(d, 0|X, Y, Z) &= \frac{1}{\sigma_u}\varphi\left(\frac{d - X\beta_X}{\sigma_u}\right)\left\{1 - p\,\Phi[\alpha(d + Y\beta_Y) + Z\beta_Z] - \right. \\ &\quad \left.(1-p)\,\Phi(\alpha\, d + Z\beta_Z)\right\}\end{aligned}$$

D Mean predicted crisis probabilities

Tables 5, 6 and 7 present the mean crisis probabilities for our sample of 97 countries (as defined in section 5.3), ordered by increasing predicted risk. The Panglossian countries are those above 20% (or – when the probability can not be computed – who had a crisis).

E Estimation

The model is estimated by maximum (log-)likelihood estimation, *i.e.* by computing the following:

$$\underset{\theta\in\mathcal{B}}{\operatorname{argmax}} \sum_{(i,t)} \log \mathcal{L}_\theta(d_{it}, c_{it}|X_{i,t-1}, Y_{i,t-1}, Z_{i,t-1})$$

where $\mathcal{B}$ is a set of constraints over parameters to ensure that constraints (11) and (12) are respected, and that $p \in [0, 1]$.

Table 5: Mean predicted crisis probabilities

Country	Crisis prob.	Had a crisis ?
Latvia	1.4	No
Romania	1.7	Yes
Uzbekistan	1.8	No
Estonia	2.2	No
Barbados	2.6	No
Czech Republic	3.1	No
Gabon	3.2	Yes
Guatemala	3.5	No
Oman	4	No
St. Vincent and the Grenadines	4.3	No
Vanuatu	4.4	No
Trinidad and Tobago	5	Yes
South Africa	5.1	No
China	5.3	No
Paraguay	6.2	Yes
Slovak Republic	6.3	No
Mauritius	6.4	Yes
Iran, Islamic Rep.	7.2	No
Dominica	7.9	No
Fiji	8.6	No
Poland	8.8	No
Rwanda	10	Yes
Solomon Islands	11.2	Yes
El Salvador	12	Yes
Malaysia	13	No
Panama	14.2	Yes
Dominican Republic	15.1	Yes
Cameroon	15.4	Yes
Costa Rica	16.6	Yes
Thailand	17.8	Yes
India	19.9	Yes
Philippines	20.2	Yes
Uruguay	20.7	Yes

Table 6: Mean predicted crisis probabilities (bis)

Country	Crisis prob.	Had a crisis ?
Honduras	21.1	Yes
Tunisia	21.7	Yes
Colombia	21.7	Yes
Senegal	21.7	Yes
Sri Lanka	22.1	No
Zimbabwe	22.9	No
Venezuela, RB	23.5	Yes
Benin	25.9	Yes
Somalia	26	Yes
Lebanon	26.2	Yes
Bangladesh	26.7	Yes
Niger	30.4	Yes
Turkey	30.4	Yes
Cote d'Ivoire	30.6	Yes
Lesotho	30.7	No
Indonesia	30.8	Yes
Ecuador	30.9	Yes
Zambia	31.4	No
Congo, Dem. Rep.	32.5	Yes
Egypt, Arab Rep.	32.7	Yes
Brazil	33.6	Yes
Papua New Guinea	34	No
Algeria	35.9	Yes
Chile	36.1	Yes
Morocco	37.2	Yes
Mexico	37.3	Yes
Kyrgyz Republic	38.6	Yes
Hungary	39.4	No
Madagascar	40.6	Yes
Kenya	41.4	Yes
Pakistan	41.5	Yes
Nigeria	42.9	Yes
Peru	44.9	Yes

Table 7: Mean predicted crisis probabilities (ter)

Country	Crisis prob.	Had a crisis ?
Maldives	47.5	No
Jordan	49.4	Yes
Ghana	49.7	Yes
Argentina	51.6	Yes
Sudan	54	Yes
Syrian Arab Republic	57.6	No
Comoros	60.6	Yes
Jamaica	63.3	Yes
Guinea-Bissau	75.5	Yes
Congo, Rep.	76.7	Yes
Sao Tome and Principe	90.1	Yes
Ethiopia	97.7	Yes
Albania	NA	No
Angola	NA	No
Kazakhstan	NA	No
Bulgaria	NA	No
Russian Federation	NA	No
Chad	NA	No
Lithuania	NA	No
Macedonia, FYR	NA	No
Croatia	NA	No
Seychelles	NA	Yes
Moldova	NA	No
Guinea	NA	Yes
Mozambique	NA	No
Tajikistan	NA	No
Tanzania	NA	Yes
Ukraine	NA	No
Vietnam	NA	Yes
Yemen, Rep.	NA	No
Serbia and Montenegro	NA	No

E.1 Constraints

Because of software requirements, the only constrained-optimization algorithm at our disposal is the L-BFGS-B method (see Byrd et al., 1995), which allows box constraints, that is each variable can be given a lower and/or upper bound.

The constraints over α, σ_u and p already fit into this category.

We deal with constraint (11) over β_Y by replacing it by a tighter constraint, in the following way:

- First, we require every regressor in Y (that is, every column of the matrix Y) to have a constant sign.
- Second, we constrain every component of β_Y to be of the sign of its corresponding column in Y.

Therefore, constraint (11) is clearly fulfilled, and the constraints over β_Y can be dealt with by the L-BFGS-B algorithm.

E.2 Non-concavity

The second issue is the fact that the log-likelihood function is not globally concave, which implies that different initial values in the optimization algorithm can lead to different local maxima.

We deal with this problem with a simple randomization algorithm.

The following procedure is repeated 10,000 times:

- Generate a random initial value. For unconstrained parameters (β_X, β_Z), a standard normal distribution is used. For sign-constrained parameters $(\beta_Z, \alpha, \sigma_u)$, a χ_1^2 distribution is used (multiplied by -1 for the relevant components of β_Y). The parameter p is either calibrated or drawn from a uniform distribution over $[0, 1]$.
- Run the L-BFGS-B algorithm using the initial value thus generated.
- If the result has a greater log-likelihood than the previous best result, keep it, otherwise discard it.

The results obtained in this way exhibit fairly good numerical stability.

F Results for alternative specifications

In tables 8 and 9, we present alternatives results, obtained by calibrating p to 0.5.

Table 8: Alternative specification with $p = 0.5$

	(1)	(2)	(3)	(4)
Debt/GDP ratio dynamics (in the absence of a crisis) (equation (9))				
β_X: Debt/GDP (t-2)	0.985***	0.984***	0.962***	0.977***
	(0.047)	(0.047)	(0.047)	(0.042)
β_X: Debt/GDP * Growth (t-1/t-2)	-1.928***	-1.831***	-1.888***	-1.762***
	(0.347)	(0.341)	(0.344)	(0.339)
β_X: Debt/GDP * Real depreciation (t-1/t-2)	1.168***	1.287***	1.412***	1.273***
	(0.163)	(0.165)	(0.159)	(0.160)
β_X: Debt/GDP * Growth fall (t-2)	0.078*	-0.077	-0.070	-0.076
	(0.035)	(0.055)	(0.056)	(0.055)
β_X: Debt/GDP * Growth fall * Panglossian (t-2)		0.212***	0.237***	0.211***
		(0.060)	(0.060)	(0.060)
β_X: Constant	0.060***	0.064***	0.073***	0.065***
	(0.014)	(0.014)	(0.013)	(0.013)
σ_u	0.106***	0.104***	0.106***	0.104***
	(0.005)	(0.005)	(0.005)	(0.005)
Debt/GDP ratio dynamics (malus in case of crisis) (equation (9))				
β_Y: Debt/GDP (t-2)	0.002	0.000	0.138***	
	(0.070)	(0.068)	(0.037)	
β_Y: Debt/GDP * US$ GDP / PPP GDP (t-2)	0.403**	0.350*		0.365***
	(0.152)	(0.151)		(0.080)
β_Y: Constant				
Debt crisis determinants (equation (10))				
α: Debt/GDP (t)	2.650***	2.847***	2.750***	2.743***
	(0.467)	(0.479)	(0.469)	(0.468)
β_Z: Log per capita PPP real GDP (t-2)	-0.331**	-0.320*	-0.353**	-0.340**
	(0.128)	(0.129)	(0.130)	(0.129)
β_Z: US$ GDP / PPP GDP (t-2)	1.368**	1.376**	1.277*	1.378**
	(0.529)	(0.534)	(0.533)	(0.531)
β_Z: Total Debt Service / Exports (t-2)				
β_Z: Constant	0.176	-0.002	0.352	0.198
	(1.045)	(1.057)	(1.055)	(1.052)
p: Sunspot Bernouilli parameter	0.500	0.500	0.500	0.500
Self-fulfilling probability	0.099	0.089	0.077	0.090
Number of observations	251	251	251	251
Log-likelihood	94.586	100.673	98.172	100.726
AIC	-165.172	-175.346	-172.343	-177.451

Table 9: Alternative specification with $p = 0.5$ (continued)

	(5)	(6)	(7)
Debt/GDP ratio dynamics (in the absence of a crisis) (equation (9))			
β_X: Debt/GDP (t-2)	1.019***	0.965***	0.958***
	(0.041)	(0.048)	(0.046)
β_X: Debt/GDP * Growth (t-1/t-2)	-1.942***	-1.988***	-1.773***
	(0.347)	(0.345)	(0.338)
β_X: Debt/GDP * Real depreciation (t-1/t-2)	1.376***	1.381***	1.285***
	(0.161)	(0.160)	(0.165)
β_X: Debt/GDP * Growth fall (t-2)	-0.074	-0.064	-0.096
	(0.056)	(0.056)	(0.058)
β_X: Debt/GDP * Growth fall * Panglossian (t-2)	0.236***	0.225***	0.235***
	(0.060)	(0.060)	(0.064)
β_X: Constant	0.056***	0.073***	0.070***
	(0.013)	(0.015)	(0.014)
σ_u	0.107***	0.106***	0.104***
	(0.005)	(0.005)	(0.005)
Debt/GDP ratio dynamics (malus in case of crisis) (equation (9))			
β_Y: Debt/GDP (t-2)		0.137*	0.032
		(0.064)	(0.068)
β_Y: Debt/GDP * US$ GDP / PPP GDP (t-2)			0.324*
			(0.153)
β_Y: Constant	0.058**	0.001	
	(0.019)	(0.033)	
Debt crisis determinants (equation (10))			
α: Debt/GDP (t)	2.865***	2.790***	1.960***
	(0.497)	(0.483)	(0.462)
β_Z: Log per capita PPP real GDP (t-2)	-0.376**	-0.354**	-0.448**
	(0.130)	(0.130)	(0.142)
β_Z: US$ GDP / PPP GDP (t-2)	1.450**	1.401**	1.058
	(0.531)	(0.533)	(0.555)
β_Z: Total Debt Service / Exports (t-2)			3.190***
			(0.749)
β_Z: Constant	0.397	0.281	0.867
	(1.059)	(1.058)	(1.113)
p: Sunspot Bernouilli parameter	0.500	0.500	0.500
Self-fulfilling probability	0.081	0.079	0.064
Number of observations	251	251	249
Log-likelihood	95.971	98.175	110.373
AIC	-167.942	-170.351	-192.746