THE EXTERNAL DEBT REPAYMENTS PROBLEMS OF LDC’S
An Econometric Model Based on Panel Data

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This paper offers an econometric analysis of the problems of repayment of external debt of
developing countries along credit rationing lines, using a panel set of data. The model presented
employs kyrto unexplored sources of information about the incidence and extent of credit
constraints. The non-linear estimation techniques pay particular attention to the panel nature of
the data by allowing for random effects to model unobserved country heterogeneity. Statistical
exogeneity of interest costs is not rejected. The model is used to investigate the role of the
‘petrodollars’ and the ‘liquidity versus solvency’ question. It is found that time dependence arises
both through persistent country-specific unobservables and through the history of debt repay-
ments problems.

1. Introduction

This paper attempts to analyze and model the determinants of external debt repayments problems of developing countries. The problem has been addressed in McFadden et al. (1985) and Hajivassiliou and O’Connell (1986). It is claimed that the specific cost charged to a country by the international bankers [in the form of a ‘spread’ over the London interbank offer rate (LIBOR)] does not perform the key role of clearing the market for international loans. Instead the allocation of scarce credit among third world countries is fundamentally carried out through quantity offers and requests. The interest rate cannot function as a pure price in this context for at least two reasons: First, as is well known from the credit rationing literature [Stiglitz and Weiss (1981)], moral hazard and other information-theoretic issues become very important in the absence of complete information about the creditworthiness of the borrowers. Second, the probability of default of a borrower depends upon the interest rate charged. Hence it might be rational for the agents to let bargaining over levels of lending perform the main allocative role in this market at a more or less exogenous price that is primarily determined by the LIBOR plus some ‘token’ spread. Empirical

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evidence [Edwards (1984)] confirms that the spreads perform only a minor role in the allocation of international credit since they do not respond very significantly to usual indicators of creditworthiness. The hypothesis that the spreads are exogenously determined is formally tested using the approach of Hajivassiliou (1986a) and is not rejected.

In section 2 three classes of models are examined. The first formulation (model A) is analogous to the analysis in Eaton and Gersovitz (1980, 1981) and proceeds with the short side rule of the disequilibrium literature, without prejudging whether in any observation period a country could or could not satisfy its notional demand for international credit.\textsuperscript{1} The second formulation (model B) attempts to exploit potentially valuable information [neglected in Eaton and Gersovitz (1980, 1981)] about the binding nature of credit constraints that is contained in the occurrence of repayments problems, such as reschedulings of debt obligations, letting these obligations fall in arrears, and requests for International Monetary Fund (IMF) assistance and/or involvement. The third modelling approach [the first versions of which appear in McFadden et al. (1985) and Hajivassiliou and O’Connell (1986)] incorporates the extra information that can be gleaned from the level of arrears on the outstanding debt service obligations of the country in question. Arrears are the most prevalent repayments problem in our sample, appearing in 17% of our country-years and in 73% of the years in which any problem occurs. Moreover, arrears are a strong one-year-ahead predictor of future problems, with 82% of countries with significant arrears in year \( t \) having a problem in the next year. This is true for only 21% of countries with no significant arrears in year \( t \).\textsuperscript{2}

Previous analyses of disequilibrium models using panel data [including Eaton and Gersovitz (1981)] have neglected the strong possibility of country heterogeneity. \textit{A priori}, countries appear to be heterogeneous along many dimensions not modelled explicitly. For example, LDC’s differ significantly in terms of colonial history and political and financial institutions. As a result the assumption of i.i.d. errors, necessary for the validity of econometric inferences drawn from such studies, becomes untenable.\textsuperscript{3} In contrast to past econometric

\textsuperscript{1}Dis-equilibrium' is a potentially misleading term A better description is 'Non-Walrasian' equilibrium: prices failing to move not because they are arbitrarily fixed, nor because of menu-type adjustment costs, but because it is not in the rational interest of the agents to actually move them (Hahn (1978)). In the context of credit markets, lenders might find it unprofitable to raise the price of funds because the probability of default on the loans could go up. On the other hand, by raising the price in times of credit shortage, they would attract an unprofitably high share of less creditworthy borrowers.

\textsuperscript{2}For the definition of 'significant' arrears, see the data appendix. Due to obvious political sensitivities, the author is not permitted by the World Bank to identify publically the countries with significant arrears.

\textsuperscript{3}The consequences of such misspecification in limited dependent variables models are discussed in Hajivassiliou (1986b). Estimation under the assumption of normality of errors yields consistent but inefficient estimates for the coefficients and inconsistent estimates for the standard errors. Methods that impose logistic distributional assumptions on the errors generally produce inconsistent coefficient estimates as well.
practice, an error-components structure is introduced in the unobservables in section 3 of this paper, with country-specific unobserved effects that persist over time.

The actual specification of the models to be estimated and the hypotheses to be tested are discussed in the second part of section 3. Section 4 presents and analyzes the empirical implementation of these models. Controversies ongoing in the context of international lending are examined. Further, we investigate the role of the past debt history of a country in affecting its creditworthiness-standing and the importance of country-specific unobservable effects. Section 5 discusses within-sample 'predictions' from the three-regime model for a subsample of countries.

The technical appendix derives the likelihood function for the three-regime level-of-arrears model with unobservable country-specific random effects and year-specific fixed effects mentioned above. The data appendix presents data sources and definitions of variables for the panel set of data used in this study, which comprises 79 countries observed over the 1970–1982 period.

2. Theoretical issues

A problem in modelling international debt behaviour is that credit transactions are non-uniform across countries and lenders. The characteristics of credit markets suggest a prevalence of quantity rather than price rationing in the equilibration process, since the price performs functions additional to its usual market-clearing one; viz. (a) it affects the distribution of income between the lending and borrowing country, (b) it performs a signalling function, and (c) it affects the probability of defaulting on a loan. Hence quantity rationing rather than the 'spread' will perform the primary market-clearing function.

Although the exogeneity assumption is not theoretically justified here, it may be motivated by recent game-theoretic work on the bargaining problem with a 'shrinking pie' as time goes by [see Binmore and Herrero (1984) and Shaked and Sutton (1984) for results and references], which implies that the eventual division will tend to strongly favour the short side of the market.

A number of other studies [e.g., Eaton and Gersovitz (1980, 1981)] have proceeded along disequilibrium lines and applied the standard switching regimes apparatus, allowing for the separate identification of supply and demand parameters. A problem with the existing studies is that they neglect information on the classification of countries as supply-constrained or de-

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4 As is well known [Heckman (1981a)], heterogeneity that persists over time may be practically indistinguishable from state dependence that arises due to past debt performance of a country affecting the bankers' creditworthiness assessment. The two questions have distinct economic implications: unobserved by the econometrician country heterogeneity needs to be modelled so as to ensure correct inferences, while one would like to be able to distinguish it from persistence arising from actual (and thus observable) past performance.
mand-constrained, provided, for example, by the observation of a rescheduling. As is well known from the econometric disequilibrium literature, the efficiency value of information on regime classification is in general quite high [Goldfeld and Quandt (1975) and Masson (1985)]. Therefore we examine models that use the actual incidence of repayments problems to classify regimes into constrained and unconstrained periods.\(^5\)

Information on arrears is valuable in assessing the severity of a lending constraint and is incorporated in our model of three regimes. The first regime is characterized by a total absence of credit rationing, as the 'notional' demand for new loans by a country falls short of the maximal supply of loans by bankers, in which case the actual new loans just meet this demand. The intermediate regime is defined by a moderate level of excess demand, a situation in which the country will have to make do with the maximal new loans the bankers are willing to supply and try to fill the gap by drawing up 'involuntary' loans by letting its debt obligations fall in arrears. However, a rescheduling or other IMF conditionality-related programs are not yet necessary as the required arrears are deemed 'acceptable' by the bankers in the sense of not exceeding a specific limit. Finally, the third regime is defined by an IMF support program and/or a rescheduling once the arrears limit becomes binding.

This three-regime model may be derived from a formal model of optimization subject to credit constraints [see Hajivassiliou and O'Connell (1986)]. Consider a country whose planners solve the dynamic program of maximizing an intertemporally separable welfare function, subject to the possibility of facing international borrowing constraints in the future. As a general notation, denote by \(CA\), \(R\) and \(A\) the current account deficit, end-of-period stock of reserves and of arrears, respectively. The solution to this dynamic program would yield targets \(\bar{CA}\), \(\bar{R}\) and \(\bar{A}\) as functions of the exogenous constraint \(\Delta S\):

\[
\bar{CA} = \bar{CA} (\cdots; \Delta S) \quad [\text{current account deficit}],
\]
\[
\bar{R} = \bar{R} (\cdots; \Delta S) \quad [\text{reserves}], \tag{1}
\]
\[
\bar{A} = \bar{A} (\cdots; \Delta S) \quad [\text{arrears}].
\]

\(^5\)Caution must be exercised in using such information, since the estimator that uses classifying information (OR) will in general be inconsistent when this information is not exact [Lec and Porter (1984)]. On the other hand, the estimator (NOR) that does not employ any classifying information is still consistent, even though it would be inefficient if the information were correct. Hajivassiliou (1986a) uses comparisons between OR and NOR through Hausman tests [Hausman (1978)] to examine the accuracy of such information.
We assume that this full solution can be well approximated by the following sequential procedure that actually elucidates the workings of such a market: Denote by \(CA^*, R^*\) and \(A^*\) the levels of current account deficit, international reserves and arrears that solve the optimization problem with the possibility of binding constraints in the future recognized, but under the assumption of no credit constraints in the current period, i.e., \(CA^* = \bar{CA}(\cdots; \Delta \bar{S} = \infty)\). Negotiations are then entered with bankers on the amount of new lending to be eventually agreed upon. The current account identity,

\[
\Delta D^* = CA^* + (R^* - R_{-1}) - (A^* - A_{-1}) \quad \text{[current account identity],}
\]

implies a demand for new borrowing \(\Delta D^*\). In general \(A^*\) will be zero as arrears are more costly than direct borrowing. The bankers then offer a maximal level of new lending they are willing to supply \((\Delta \bar{S})\). We assume that the bargaining process will result in the short side getting its way [see Binmore and Herrero (1984) and Shaked and Sutton (1984)]. In cases when the current credit constraint is binding for the country \((\Delta D^* > \Delta \bar{S})\), the administrators are left with a set of irreconcilable targets \(CA^*, R^*\) and \(A^*\). We therefore postulate a quadratic loss function in the deviations of the levels \(CA^*, R^*\) and \(A^*\) from their chosen values \(\bar{CA}, \bar{R}\) and \(\bar{A}\). That is,

\[
\min_{CA,\ \bar{R},\ \bar{A}} \{ ((CA^* - \bar{CA}), (R^* - \bar{R}), (A^* - \bar{A})) \}
\]

\[ \cdot W \cdot \{ ((CA^* - \bar{CA}), (R^* - \bar{R}), (A^* - \bar{A})) \}', \]

subject to

\[
\Delta D^* - \Delta \bar{D} = (CA^* - \bar{CA}) + (R^* - \bar{R}) + (A^* - \bar{A}) \geq \Delta D^* - \Delta \bar{S},
\]

where \(W\) is a positive definite matrix. Since the constraint can be simplified to

\[
\bar{CA} + (\bar{R} - R_{-1}) + (\bar{A} - A_{-1}) \leq \Delta \bar{S},
\]

and the administrators know exactly the values of unconstrained targets \(R^*\),

\footnote{It is irrelevant for our purposes how the bankers would reallocate their portfolio in case the country takes only part of the offered credit. The lenders are assumed only to choose \(\Delta \bar{S}\) rationally.}
$A^*$ and $CA^*$, the solution to this constrained loss-minimization problem will be linear in $CA^*$, $R^*$ and $A^*$, taking the form

$$(C\bar{A}, \bar{R}, \bar{A})' = M \cdot (CA^*, R^*, A^*, \Delta S)'$$

(5)

where $M$ is a $3 \times 4$ matrix of coefficients whose values depend on the elements of $W$.

Consider the assumptions required to obtain a three-regime specification of the main model, viz. with $A^* = 0$, regime 1 is defined by non-binding credit constraints in period $t$ as $\Delta D^* < \Delta S$.

Alternatively suppose that the credit constraint is binding ($\Delta D^* > \Delta S$) and assume that the weights in the loss function $W$ are such that always $CA^* = C\bar{A}$ and $R^* = \bar{R}$, i.e., it is deemed extremely costly (e.g., for political purposes) to deviate from these two targets. Then $\Delta \bar{D} = \Delta \bar{S}$, which implies from constraint (4)

$$\Delta D^* - \Delta \bar{D} = \Delta D^* - \Delta \bar{S} = \bar{A} - 0 = \bar{A},$$

provided $\bar{A}$ is considered an acceptable level of arrears by bankers; this defines the second regime of moderate excess demand.

Lastly, when $\bar{A}$ is unacceptable to bankers, a real repayments problem faces the country, a situation that defines the third regime. It is important to note that in this ‘crisis’ case the only information used is that arrears desired by a country to fill up its excess demand gap exceed the level acceptable to bankers (see the technical appendix). Nothing is said about actual transactions in such a case (e.g., new loans agreed upon and level of arrears maintained). Negotiations on such issues, which will involve third parties like the IMF, fall outside the scope of analysis of this paper.

The three-regime model is a highly non-linear econometric model, containing elements of four classes of models of limited dependent variables. The model simultaneously exhibits (a) a probit structure since an indicator variable identifies the first regime of no debt repayments problems from the repayments problems regimes 2 and 3, (b) a tobit structure in that the observed level of arrears can be either 0 or positive, (c) a switching regressions aspect as the new flow of lending to a country ($\Delta \bar{D}$) can be either equal to $\Delta D^*$ in regime 1 or to $\Delta S$ in regime 2, and finally (d) an endogenously missing data structure since, when regime 3 is observed, we do not attempt to identify the level of arrears and the new funds flowing to this economy.

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7 This two-stage optimization problem is analogous to Jorgenson's investment function model and hence exhibits the same theoretical limitations: Instead of solving the intractable multi-period optimization problem, a partial-adjustment mechanism is postulated in the single-period version of the model.
3. Stochastic specification

3.1. Country heterogeneity

An issue neglected in all previous work on LDC debt performance has been the temporal structure of unobservable variables, the implicit assumption being that country-year shocks are all independently and identically distributed. In a panel model, temporal dependence can arise in at least two ways and hence can be a source of serious misspecification. First, heterogeneity that persists over time appears a priori important, since countries clearly differ in terms of colonial history and political, religious and financial institutions, all of which may affect a country's attitude towards borrowing and defaulting and the lenders' attitudes towards the borrowing country. Such heterogeneity, which introduces serial correlation, seems an inevitable result of modelling debt performance as a function of a small number of macroeconomic variables. Secondly, serial correlation may be induced by learning processes that rely on a history of past repayments crises as a good predictor of future debt crises, by the role asset accumulation plays in the problem, or by our failure to address questions about the duration (actual or anticipated) of debt crises.9

Heterogeneity can be incorporated in our models by allowing the disturbance terms to have an error-components structure:

\[ \epsilon_{it} = \eta_i + \nu_{it} \tag{6} \]

where \( \nu_{it} \) is an i.i.d. normal random variable and \( \eta_i \) is a country-specific normal random variable, uncorrelated with \( \nu_{it} \). The relative importance of the country effect \( \eta \) can be assessed by comparing the estimated variances of \( \eta \) and \( \nu \). In our estimations below, we introduce for the first time in disequilibrium models country-specific unobservables. The technical appendix derives the likelihood expressions under such error-components structures.

3.2. Specification of demand and supply

We start from factors already identified in the literature as determining the creditworthiness of a country and hence the supply of lending, such as the

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5 An exception is McFadden et al. (1985) which allows for country-specific unobserved effects with a generalized probit estimation technique.

9 In McFadden et al. (1985), likelihood ratio tests suggested the presence of strong state dependence, with a relatively weaker, but statistically significant effect of heterogeneity. Note that the estimation of the heterogeneity model in that study did not make specific allowance for the presence of a lagged dependent dummy variable among the explanatory variables, which, as explained in the technical appendix below, causes inconsistency.
ratio of outstanding debt to exports. This measures the extent to which exports, the main source of foreign exchange, can cover the external indebtedness of the country.

The ratio of debt service due over exports is considered as a further creditworthiness indicator, since it describes the ability of an economy to finance its yearly interest and principal obligations that are a pressing short-run concern. Separation of interest from principal repayments is undertaken in order to shed some light on the on-going 'liquidity versus solvency' controversy. Presumably, prompt receipt of interest payments from a country reflects solvency.

The ratio of reserves to imports is a measure of how long an economy can finance its imports by using its stock of reserves without seeking refuge in higher levels of external borrowing. This ratio may both indicate high creditworthiness and low demand for new loans, ceteris paribus, since existing stocks of reserves can be used to do such financing.

Real GNP per capita reflects both aid motivations by the suppliers of new lending and the degree of financial well-being of a country that signifies high creditworthiness. Similar considerations apply to the growth rate of real income. A high exports/GDP ratio may be viewed as an undesirable characteristic by international bankers, because it reflects vulnerability to price shocks and to falling demand for its exported goods. On the other hand, the planners of a country with a highly open economy are more likely to be disciplined in their international financial dealings and less likely to repudiate, recognizing the severe losses from a drying-up of international credit. Past repayments problems, reflected in IMF arrangements, reschedulings and/or significant arrears outstanding, could be strong indicators of a lack of creditworthiness.

Among factors that should mainly affect the demand for new loans are: the debt service obligations due, including any accumulated arrears, the level of imports, and the real income generated in an economy and its growth rate. Concerning the latter, see McFadden et al. (1985). High debt obligations could be expected to raise demand for new loans in order to help meet the existing obligations. The available foreign exchange reserves are an alternative source

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10According to the first view, the international capital markets are not frictionless, hence a debt crisis might be induced by a lack of liquidity to a financially sound borrower. The 'solvency' view maintains that credit crises are manifestations of insolvency.

11One would prefer to introduce also a measure of 'non-compressible' imports, i.e., imports that a country finds very difficult to reduce in a debt crisis situation (e.g., oil, basic foodstuffs, primary inputs, etc.). Lack of satisfactorily consistent data precluded the construction of such measures.

12One could use instead indirect measures of flows of aid funds to particular countries in case such measures were available.

13Alternative measures, based on the number of all past problems beginning from 1970, suggested that the bankers have 'short memories', i.e., they attach most weight to any repayments problem(s) in the immediately preceding period.
of financing current account deficits; hence they should affect negatively the demand for new foreign loans. A rapidly expanding economy might impose high requirements on external borrowing. On the other hand, high levels of real per capita income might characterize a well managed, affluent economy, less likely to need huge external debt finance.

With these considerations in mind, the most general formulations we try for the (notional) demand and supply functions and for the limit on arrears are\textsuperscript{14}

\[
\text{DEMAND} = d_1 + d_2 \times \left( \frac{\text{Debt service due/Exports}}{} \right) + d_3 \times \left( \frac{\text{Reserves/Imports}}{} \right) + d_4 \times \left( \frac{\text{Real GNP per capita}}{} \right) + d_5 \times \left( \frac{\text{Growth rate of real GNP}}{} \right) + d_6 \times \left( \frac{\text{Imports/GDP}}{} \right) + d_7 \times \text{POST73}, \tag{7}
\]

\[
\text{SUPPLY} = s_1 + s_2 \times \left( \frac{\text{Total debt outstanding/Exports}}{} \right) + s_3 \times \left( \frac{\text{Interest due/Exports}}{} \right) + s_4 \times \left( \frac{\text{Principal due/Exports}}{} \right) + s_5 \times \left( \frac{\text{Reserves/Imports}}{} \right) + s_6 \times \left( \frac{\text{Real GNP per capita}}{} \right) + s_7 \times \left( \frac{\text{Growth rate of real GNP}}{} \right) + s_8 \times \left( \frac{\text{Exports/GDP}}{} \right) + s_9 \times \left( \frac{\text{Indicator for past IMF support and/or rescheduling}}{} \right) + s_{10} \times \left( \frac{\text{Indicator for past arrears}}{} \right) + s_{11} \times \text{POST73} \tag{8}
\]

\[
\text{ARREARS LIMIT} = a_1 + a_2 \times \left( \frac{\text{Total debt outstanding/Exports}}{} \right) + a_3 \times \left( \frac{\text{Debt service due/Exports}}{} \right) + a_4 \times \left( \frac{\text{Real GNP per capita}}{} \right) + a_5 \times \left( \frac{\text{Growth rate of real GNP}}{} \right) + a_6 \times \left( \frac{\text{Exports/GDP}}{} \right) + a_7 \times \text{QRSSIMFL} + a_8 \times \text{POST73}, \tag{9}
\]

where \text{POST73} is a dummy variable taking the value 1 after 1973. The data sources and construction of variables are discussed in the data appendix.

\textsuperscript{14}All explanatory variables are lagged one year in order to attenuate simultaneity issues. The main estimations were also carried out with contemporaneous variables where appropriate, with no significant changes. Formal tests of lack of simultaneity could be developed by generalizing methods in Hajivassiliou (1986a).
Table 1
Estimates of three-regime model; dependent variables are DVDEL, DNEW and ARR (asymptotic t-statistics in parentheses) ¹

<table>
<thead>
<tr>
<th>Variable (lagged one year)</th>
<th>New loan demand</th>
<th>New loan supply</th>
<th>Limit on arrears</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.3470</td>
<td>0.4376</td>
<td>0.2195</td>
</tr>
<tr>
<td></td>
<td>(3 223)</td>
<td>(6 988)</td>
<td>(0.571)</td>
</tr>
<tr>
<td>Debt service due/Exports</td>
<td>6.5243</td>
<td>—</td>
<td>1.8449</td>
</tr>
<tr>
<td></td>
<td>(25 267)</td>
<td></td>
<td>(2.394)</td>
</tr>
<tr>
<td>Real GNP/Capita</td>
<td>-0.3911</td>
<td>0.0203</td>
<td>-0.0814</td>
</tr>
<tr>
<td></td>
<td>(5 261)</td>
<td>(0.493)</td>
<td>(0.383)</td>
</tr>
<tr>
<td>Growth rate of real GNP</td>
<td>0.0963</td>
<td>0.0597</td>
<td>0.0785</td>
</tr>
<tr>
<td></td>
<td>(0.120)</td>
<td>(0.167)</td>
<td>(0.041)</td>
</tr>
<tr>
<td>Imports/GDP</td>
<td>0.9489</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>(4.885)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reserves/Imports</td>
<td>—</td>
<td>0.0771</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>(0.890)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exports/GDP</td>
<td>—</td>
<td>-0.0413</td>
<td>-0.3060</td>
</tr>
<tr>
<td></td>
<td>(0.369)</td>
<td>(0.332)</td>
<td></td>
</tr>
<tr>
<td>Debt/Exports</td>
<td>—</td>
<td>0.0875</td>
<td>0.1563</td>
</tr>
<tr>
<td></td>
<td>(2.640)</td>
<td>(1.169)</td>
<td></td>
</tr>
<tr>
<td>Indicator for IMF support</td>
<td>—</td>
<td>-0.1451</td>
<td>-1.3303</td>
</tr>
<tr>
<td>or rescheduling</td>
<td></td>
<td>(1.932)</td>
<td>(6.082)</td>
</tr>
<tr>
<td>Indicator for arrears</td>
<td>—</td>
<td>-0.3058</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>(6.480)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest due/Exports</td>
<td>—</td>
<td>0.4552</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>(0.505)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Principal due/Exports</td>
<td>—</td>
<td>0.2146</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>(1.126)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard deviation</td>
<td>1.2759</td>
<td>0.4679</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(8 897)</td>
<td>(20 284)</td>
<td></td>
</tr>
<tr>
<td>Correlation</td>
<td>0.2788</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(4 785)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Likelihood value</td>
<td>-1668.386</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹ DVDEL = 1 if either a rescheduling is requested and/or an IMF agreement is in effect; DNEW = total new debt obtained within the period (scaled by the flow of exports), and ARR = total significant principal and interest outstanding arrears on debt obligations

4. Empirical findings

Table 1 contains estimates of the three-regime model under i.i.d. assumptions. We find the demand for debt to be increasing strongly in the debt service to exports ratio, possibly reflecting a desire for new debt to keep financing accumulated obligations. Demand is also found to rise with the imports to GDP ratio, presumably because this ratio implies a high need for
foreign exchange financing. The significantly negative coefficient of per capita income, $d_4$, suggests that relatively affluent countries have a lower need for external debt.

Proceeding to supply factors, we find that history of repayments problems has a strongly depressing effect on the availability of new loans, especially so if the previous period was one with non-zero significant arrears. The coefficient $s_2$ is significantly positive (though of a very small magnitude) suggesting that bankers keep supplying funds to countries with which they have a history of commitment. Though statistically not significant, a high reserves to import ratio, supposedly indicating a creditworthy economy, comes out with a positive coefficient. The coefficient $s_3$ turns out positive but insignificant. The positive signs once again suggest that bankers may be influenced by past commitment considerations. However, the fact that $s_4$ is significantly smaller than unity has an interpretation that liquidity problems may arise if the bankers refuse to roll over principal obligations one for one.

Among the determinants of the arrears limit, debt service is found to have a significantly positive effect, suggesting that bankers may monitor arrears as a percentage of debt obligations. The stock of debt also has a positive while insignificant effect. As expected, past repayments problems tighten the arrears limit significantly. Exports to GDP come in with a negative (but statistically insignificant) sign both on the supply side and on the arrears limit, which may mean that bankers view a high exports ratio as a ‘bad’ thing – high degree of openness implying that the economy in question is too vulnerable to the vagaries of commodities market shocks and to the policies of the industrialized world. We find a significantly positive correlation (0.28) between demand and supply unobservables, with most of the shocks coming from the demand side ($\sigma_D = 1.28$ versus $\sigma_S = 0.47$).

![Diagram showing regimes with and without problems](image-url)
To examine the robustness of the specification of the three-regime model, we next consider related ‘limited information’ models that only investigate the incidence of crises. Qualitatively, one may think of the set-up as one with three relevant ‘choices’: (1) no debt repayments problem, (2) significant arrears, but no real ‘crisis’, and (3) debt crisis. A natural way of modelling this is through a nested trinomial logit (NTNL) model [McFadden (1981)] with the structure described in fig. 1.

Table 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>NTNL_1</th>
<th></th>
<th>NTNL_2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate</td>
<td>t-stat.</td>
<td>Estimate</td>
<td>t-stat.</td>
</tr>
<tr>
<td>Debt/Exports * D3^a</td>
<td>0.6804</td>
<td>3.218</td>
<td>0.3691</td>
<td>1.907</td>
</tr>
<tr>
<td>* D2</td>
<td>0.4312</td>
<td>2.658</td>
<td>0.2733</td>
<td>1.546</td>
</tr>
<tr>
<td>Growth rate in real GDP * D3</td>
<td>-5.9075</td>
<td>-1.851</td>
<td>-1.4367</td>
<td>-0.531</td>
</tr>
<tr>
<td>* D2</td>
<td>0.4853</td>
<td>0.327</td>
<td>2.6196</td>
<td>1.442</td>
</tr>
<tr>
<td>Debt service/Exports * D3</td>
<td>3.3363</td>
<td>3.035</td>
<td>2.3619</td>
<td>2.134</td>
</tr>
<tr>
<td>* D2</td>
<td>2.1022</td>
<td>2.416</td>
<td>1.0515</td>
<td>1.060</td>
</tr>
<tr>
<td>Exports/GDP * D3</td>
<td>1.5530</td>
<td>0.696</td>
<td>-0.0805</td>
<td>-0.048</td>
</tr>
<tr>
<td>* D2</td>
<td>0.5024</td>
<td>0.524</td>
<td>-0.1142</td>
<td>-0.095</td>
</tr>
<tr>
<td>IMFHIST * D3^b</td>
<td>0.3538</td>
<td>2.098</td>
<td>-0.0128</td>
<td>-0.098</td>
</tr>
<tr>
<td>* D2</td>
<td>-0.5743</td>
<td>-3.862</td>
<td>-0.3896</td>
<td>-2.494</td>
</tr>
<tr>
<td>Imports/GDP * D3</td>
<td>-1.7586</td>
<td>-0.903</td>
<td>-0.1570</td>
<td>-0.110</td>
</tr>
<tr>
<td>* D2</td>
<td>-0.0207</td>
<td>-0.025</td>
<td>0.3084</td>
<td>0.295</td>
</tr>
<tr>
<td>Reserves/Imports * D3</td>
<td>-6.7274</td>
<td>-3.144</td>
<td>-4.2955</td>
<td>-2.429</td>
</tr>
<tr>
<td>* D2</td>
<td>-1.2297</td>
<td>-3.012</td>
<td>-1.4664</td>
<td>-2.933</td>
</tr>
<tr>
<td>Real GNP/Capita * D3</td>
<td>-0.5024</td>
<td>-1.783</td>
<td>-0.4472</td>
<td>-2.066</td>
</tr>
<tr>
<td>* D2</td>
<td>-0.6538</td>
<td>-4.374</td>
<td>-0.4455</td>
<td>-2.547</td>
</tr>
<tr>
<td>RSSHIST * D3^c</td>
<td>-0.2107</td>
<td>-1.078</td>
<td>-0.1120</td>
<td>-0.571</td>
</tr>
<tr>
<td>* D2</td>
<td>-0.1214</td>
<td>-0.614</td>
<td>-0.0052</td>
<td>-0.025</td>
</tr>
<tr>
<td>REG2LAG * D3^d</td>
<td>—</td>
<td>—</td>
<td>2.0782</td>
<td>3.136</td>
</tr>
<tr>
<td>* D2</td>
<td>—</td>
<td>—</td>
<td>3.3250</td>
<td>13.114</td>
</tr>
<tr>
<td>REG3LAG * D3^d</td>
<td>—</td>
<td>—</td>
<td>2.3908</td>
<td>6.807</td>
</tr>
<tr>
<td>* D2</td>
<td>—</td>
<td>—</td>
<td>2.1726</td>
<td>5.438</td>
</tr>
<tr>
<td>Constant * D3</td>
<td>-0.9326</td>
<td>-1.437</td>
<td>-1.1482</td>
<td>-2.473</td>
</tr>
<tr>
<td>* D2</td>
<td>0.0887</td>
<td>0.330</td>
<td>-1.2167</td>
<td>-3.490</td>
</tr>
<tr>
<td>Lambda^a</td>
<td>1.1852</td>
<td>2.754</td>
<td>0.6467</td>
<td>1.580</td>
</tr>
</tbody>
</table>

^a D3 = dummy variable = 1 for regime 3, 0 otherwise; D2 = dummy variable = 1 for regime 2, 0 otherwise.

^b IMFHIST = cumulated number of years since 1970 with IMF involvement.

^c RSSHIST = cumulated number of reschedulings since 1970.

^d REG2LAG = dummy variable = 1 for regime 2 in year (t−1); REG3LAG = dummy variable = 1 for regime 2 in year (t−1).

^e Dissimilarity parameter λ (see text)
In this model 'choices' 2 and 3 correspond to debt repayments problems of different degrees of severity. Hence one might expect higher substitutability between these two, a possibility the standard trinomial logit (TNL) model [McFadden (1973)] cannot allow for. A 'dissimilarity' parameter, \( \lambda \), is associated with node \( N \) and measures the degree to which within-node alternatives differ from across-node ones. The standard TNL is a special case of the NTNL model when \( \lambda \) equals 1, which can be tested by classical methods [McFadden (1981)].

We present in Table 2 estimations that pool together the data neglecting their panel nature. One should exercise caution in interpreting these results, given the random-effects findings of Hajivassiliou (1985). The same set of explanatory variables is used as in Table 1. Since these variables are country characteristics that take the same value for all three regimes, in order to achieve identification we normalize on the first regime, by interacting each variable with dummy variables \( D_3 \) and \( D_2 \), one for each of the other regimes. Thus this procedure identifies the differential impact of a given explanatory variable on the choice probabilities of the second and third regimes, over and above its impact on those of the first regime.

The signs of the estimated effects found in Table 1 are confirmed by the results in Table 2. The probability of a 'crisis' (regime 3) is raised significantly by high debt outstanding to exports and debt service payments to export ratios; it is lowered significantly by a high growth rate of GNP and a high real income per capita. Within the shortcomings of the limited information NTNL approach, we attempt to examine how 'long' memories for past debt problems the bankers have, by including variables \( IMFHIST \) and \( RSSHIST \). These variables are cumulated counts of past years with repayments problems: years in which IMF conditionality-related programs were in effect and years of requesting/signing reschedulings of debt obligations, respectively. The choice of regime in the previous period is entered as \( REG2LAG \) and \( REG3LAG \) in model version II. It is generally found that the incidence of most recent problems is more important than the cumulated number of problems in the more distant past, the lagged 'choice' of regime exhibiting extremely high explanatory power.\(^{15}\)

Given its 'reduced form' nature, the trinomial logit model does not allow separate identification of \( D \) and \( S \) parameters. In contrast, the basic two-

\(^{15}\)Appropriate tests, developed in Hausman and McFadden (1984), indicate that the simple TMNRL model is not rejected against the nested model. The test results were as follows:

\[
\begin{array}{cccc}
| H_0 & H_1 & \text{LM} & \text{LR} & \text{Wald} \\
| TNL_1 & NTNL_1 & 0.187 & 0.201 & 0.186 & \chi^2 10\%(1) = 2.706 \\
| TNL_II & NTNL_II & 0.782 & 0.650 & 0.746 &
\end{array}
\]

One should note that the dissimilarity parameter \( \lambda \) is very poorly determined in \( NMNL_{III} \); not only we are unable to reject the MNL value of 1 (\( t = 0.864 \)), but we also cannot reject the hypothesis of a \( \lambda \) equal to 0.
regime (excess demand, excess supply) models allow such identification, and we now summarize the results from these models. The detailed estimates can be obtained from the author upon request. As in Eaton and Gersovitz (1981), model A employed the method that does not use classifications on regimes, but simultaneously estimates the classification most consistent with the data. Model B classified a period as constrained if it involved requests for reschedulings, IMF agreements, and/or significant arrears, i.e., it lumped together the 'moderate excess demand' and 'crisis' regimes into a single supply-constrained regime. We found no dramatic changes in the signs of the coefficients. The actual estimation results without classifying information, however, were not very close to the ones that employed the classification rule above. This suggests that this classification may be inaccurate or that neglecting classifying information can lead to unreliable estimates.\footnote{The use of a Hausman test as explained in Hajivassiliou (1986) gave a $\chi^2(15)$ value of 76.3, which strongly rejects accurate classification.}

An interesting finding was that now the principal due to exports ratio on the supply side became strongly significant (asymptotic $t$-statistic higher than 7), still with magnitude less than unity. This again suggests that liquidity pressures build up on countries with high external indebtedness, since the bankers seem unwilling to roll-over principal obligations fully. A further finding was that in both two-regime models the shocks seemed to be coming more from the supply rather than the demand side ($\sigma_s = 0.39$, $\sigma_d = 0.28$), which may suggest that the three-regime modelling is a sensible way of refining the supply side into supply of new loans and monitoring of arrears.

The credit rationing two-regime models were also used to test the assumption of exogeneity of interest rate on which the main modelling approach here rests. The appropriate $\chi^2(2)$ test statistics gave 4.32 and 3.87 for model A and B, respectively, neither of which rejecting exogeneity at the 5% level.\footnote{The asymptotically optimal Lagrange multiplier test in this case correspond to testing the significance of the residuals from the reduced form for the interest rate when included as additional regressors in the $D$ and $S$ equations [Hajivassiliou (1986a)].}

We also tested the ‘petrodollars’ hypothesis using the three-regime model. According to this view, the current debt problems in international capital markets have been caused to a large extent by ‘too easy’ availability of credit following the influx of ‘petrodollars’ in search of a borrower, that took place after the 1973 events, and by the developing countries attempting to maintain their declining standards of living after the oil shock by obtaining higher external debts. The POST73 dummy was found statistically insignificant on all three sides.\footnote{The likelihood ratio and Lagrange multiplier $\chi^2$ statistics were equal to 2.1849 and 2.2454, respectively, against a 5% critical value $\chi^2(3)$ of 7.815}

Results in table 3 employ the main econometric innovation of this paper, namely introduction of (random) country heterogeneity into the three-regime
Table 3
Panel estimates of three-regime model; dependent variables are $DVDEL$, $DNEW$, and $ARR$ (asymptotic $t$-statistics in parentheses).\(^a\)

<table>
<thead>
<tr>
<th>Variable (lagged one year)</th>
<th>New loan demand</th>
<th>New loan supply</th>
<th>Limit on arrears</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>$-0.342$</td>
<td>$0.460$</td>
<td>$0.0356$</td>
</tr>
<tr>
<td></td>
<td>$(2.051)$</td>
<td>$(8.841)$</td>
<td>$(0.067)$</td>
</tr>
<tr>
<td>Debt service due/Exports</td>
<td>$5.650$</td>
<td>$-$</td>
<td>$1.983$</td>
</tr>
<tr>
<td></td>
<td>$(20.072)$</td>
<td></td>
<td>$(2.680)$</td>
</tr>
<tr>
<td>Real GNP/Capita</td>
<td>$-0.439$</td>
<td>$-$</td>
<td>$-$</td>
</tr>
<tr>
<td></td>
<td>$(5.405)$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imports/GDP</td>
<td>$1.149$</td>
<td>$-$</td>
<td>$-$</td>
</tr>
<tr>
<td></td>
<td>$(6.205)$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reserves/Imports</td>
<td>$-$</td>
<td>$0.116$</td>
<td>$-$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$(1.274)$</td>
<td></td>
</tr>
<tr>
<td>Debt/Exports</td>
<td>$-$</td>
<td>$0.0625$</td>
<td>$0.146$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$(1.915)$</td>
<td>$(1.225)$</td>
</tr>
<tr>
<td>Indicator for IMF support or rescheduling</td>
<td>$-$</td>
<td>$-0.175$</td>
<td>$-1.375$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$(2.358)$</td>
<td>$(6.435)$</td>
</tr>
<tr>
<td>Indicator for arrears</td>
<td>$-$</td>
<td>$-0.261$</td>
<td>$-$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$(4.963)$</td>
<td></td>
</tr>
<tr>
<td>Interest due/Exports</td>
<td>$-$</td>
<td>$0.436$</td>
<td>$-$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$(0.485)$</td>
<td></td>
</tr>
<tr>
<td>Principal due/Exports</td>
<td>$-$</td>
<td>$0.0624$</td>
<td>$-$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$(0.310)$</td>
<td></td>
</tr>
<tr>
<td>Standard deviation</td>
<td>$0.944$</td>
<td>$0.453$</td>
<td>$-$</td>
</tr>
<tr>
<td></td>
<td>$(2.375)$</td>
<td>$(20.975)$</td>
<td></td>
</tr>
<tr>
<td>Correlation</td>
<td>$0.182$</td>
<td>$\theta$</td>
<td>$-$</td>
</tr>
<tr>
<td></td>
<td>$(3.828)$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Random effects</td>
<td>$\eta$</td>
<td>$\theta$</td>
<td>$-$</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>$0.369$</td>
<td>$0.109$</td>
<td>$-$</td>
</tr>
<tr>
<td></td>
<td>$(7.529)$</td>
<td>$(6.425)$</td>
<td></td>
</tr>
<tr>
<td>Likelihood value</td>
<td>$-1607.892$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^aDVDEL = 1\) if either a rescheduling is requested and/or an IMF agreement is in effect, $DNEW = \text{total new debt obtained within the period (scaled by the flow of exports)}$; $ARR = \text{total significant principal and interest outstanding arrears on debt obligations.}$

The country-specific unobservables appear important, with the demand-side country effect having a standard deviation $\sigma_\eta$ equal to 0.369 (with asymptotic $t = 7.53$) and the supply-side effect $\theta$ with $\sigma_\theta = 0.109$ ($t = 6.43$). In general, changes in the $t$-statistics due to the random effects estimation are of

\(^{19}\)To lessen tractability problems, we assume that the random effects on the supply- and demand-sides are uncorrelated. This would be violated in case part of the unobserved country heterogeneity arises due to common factors on the $D$ and $S$ sides not modelled explicitly.
the order of 10 to 25 percent. There is some evidence of stronger demand-side heterogeneity – $\sigma_D$ falls from 1.28 to 0.94 and its $t$-statistic from 8.90 to 2.38 after the introduction of the random effects. The past repayments problems dummies remain significant, though they lose some of their explanatory power. This suggests that the reason we were finding past history to be an important factor under i.i.d. assumptions was not due to neglecting country heterogeneity.

5. Ex post predictions of debt repayments crises

In this section, within-sample ‘predictions’ from the three-regime model are discussed, first as an illuminating check on the specification of the model and second to examine how serious neglecting unobservable heterogeneity can be.

Probabilities of debt repayments ‘crises’ (regime 3) were computed and graphed for a selected subsample of countries. Figs. 2 and 3 present the results for Brazil and Chile, Latin American economies with well-known external debt histories. Series $P3$ uses the point coefficient estimates of table 1 that neglect country heterogeneity. Series $P3Z$, $P3DP$, and $P3SP$ employ the random effects estimates of table 3 and are probabilities conditional on particular values of the random effects. $P3Z$ assumes that both demand and supply effects are at their (unconditional) means of zero. $P3DP$ follows the unfavourable scenario in which the unobserved demand effect by a country exceeds its zero mean by one (estimated) standard deviation, while the supply effect is below the mean by one standard deviation. $P3SP$ pictures the converse situation. In parts (b) of the figures, $P3$ is plotted alongside upper ($UB$) and lower ($LB$) asymptotic confidence bounds of one estimated (asymptotic) standard deviation $\tilde{\sigma}_{P3}$.

The first general conclusion is that the problem of implausibly high crisis probabilities uniformly predicted by various ‘reduced-form’ models in McFadden et al. (1985) is overcome by the three-regime model of this paper. Secondly, heterogeneity effects appear important in that fairly probable values of such effects change substantially the crisis probabilities. Moreover, the range from $P3DP$ to $P3SP$ is of the same order of magnitude and generally wider than the range between the asymptotic confidence bounds. Thirdly, the probabilities track fairly well events in country histories.

The debt problems of Brazil appear wholly oil-shock-related: the probabilities underwent a distinct jump after 1974 and never receded to their pre-oil-shock levels. In the case of Chile, the political and economic upheavals of 1971–1975 are captured by steeply rising crisis probabilities. A drastic and

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20 $\tilde{\sigma}_{P3}$ was calculated through the usual Taylor-series asymptotic expansion,

$$
\text{Avar}(P3(\hat{\beta})) = \frac{\partial P3}{\partial \hat{\beta}} (\hat{\beta}) \cdot V(\hat{\beta}) \cdot \frac{\partial P3}{\partial \hat{\beta}} (\hat{\beta})',
$$

where $V(\hat{\beta})$ is $\text{Avar}(\hat{\beta})$. 
Fig. 2 Brazil.
Fig. 3. Chile
apparently ill-timed liberalization policy and a major collapse in the price of copper in 1978–1979 renewed the pressures on the economy.

The prediction exercise was carried out for other Latin American countries with comparable results.

6. Conclusions

This paper presented and estimated models of lending in international capital markets, with the allocation of credit being primarily carried out through quantity rationing at (statistically) exogenous interest rates. New sources of information about the possibility and extent of credit constraints were explored. The main findings confirm the previously documented importance of creditworthiness indicators on the supply of funds and on limits on ‘acceptable’ levels of arrears. The threat to repudiate, the significance of which was first stressed by Eaton and Gersovitz (1981), governs the willingness of bankers to accommodate moderate levels of obligations in arrears. We also find that a history of debt repayments problems has a strongly dampening effect on the availability of new funds and a tightening of limits on arrears.

The evidence suggests that high levels of debt obligations force bankers to maintain a flow of funds to such customers.

Demand factors identified here include: the use of existing foreign exchange reserves as an alternative to external debt, high imports levels inducing high demand for foreign debts, and a lower demand by relatively affluent borrowers, other things being equal. The stochastic shocks are found to arise primarily from the demand side. This finding is reversed in two-regime models which do not distinguish supply of pure loans from allowing arrears to rise. High debt obligations are accompanied by high demand for new funds, possibly attempting to service the existing obligations.

Substantial differences in results were observed in the two-regime models when classifying as credit-constrained an economy that asks to reschedule its debt obligations, requests/accepts IMF involvement, or lets its obligations go into arrears. This may suggest that such a classifying rule is misleading or that neglecting classifying information leads to very inaccurate estimates. Weak evidence is found for the claimed glut of ‘petrodollars’ after the 1973 oil shock leading to higher levels of international lending. The hypothesis that liquidity problems induce external debt crises even for overall solvent borrowers was supported. The claimed exogeneity of the interest rate is not rejected.

Within-sample ‘predictions’ of probabilities of debt crises were used for testing the specification of the models with favourable results. Analogous predictions under alternative scenarios on the LDCs’ external debt situation can serve to examine the effects of such alternative scenarios.

Explicit allowance for the possibility of country heterogeneity establishes a strong role for country-specific persistent unobservable effects, without
eliminating the importance of a history of past repayments problems. The issues of duration of debt repayments crises and the role of economic conditions in the developed countries in affecting probabilities of debt problems in the developing nations warrant future study.

Technical appendix

The likelihood function for the three-regime model with D and S random effects

We modify the three-regime model in McFadden et al. (1985) and Hajivassiliou and O'Connell (1986) to incorporate heterogeneity, and the likelihood function is derived under 'random effects' assumptions on the demand and supply of new loans.\textsuperscript{21} Fixed year effects are handled as an extra set of $2T$ parameters. [The i.i.d. case is presented in appendix B of McFadden et al. (1985).]

Stochastic elements enter at three points. The notional demand $N^D$ curve and the maximal supply $N^S$ are linear functions of predetermined variables with additive random shocks for each country and period:

$$N^D_{it} = D_{it} + \eta_i + \varepsilon^D_{it}, \quad (A.1)$$

$$N^S_{it} = S_{it} + \theta_i + \varepsilon^S_{it}. \quad (A.2)$$

Joint normality assumptions are made, with the vector $(\varepsilon^D_{it}, \varepsilon^S_{it})$ mutually independently distributed from the vector $(\eta_i, \theta_i)$ for all $i$ and $t$.\textsuperscript{22} We use the natural notation for the variances of the four errors. Also let $\rho = \text{corr}(\varepsilon^D, \varepsilon^S)$ and $\rho_{\eta \theta} = \text{corr}(\eta, \theta)$ and characterize the arrears limit $L^*$ by an exponential random variable with cumulative distribution function:

$$\text{Prob}(L^* < l) = 1 - \exp(-Bl - C). \quad (A.3)$$

$B$ and $C$ are linear functions of predetermined variables and contain basically the same country characteristics entering the overall credit limit, since $L^*$ is imposed by suppliers. The non-negativity property of the exponential provides a natural characterization of a lower limit on a financial stock like arrears.

\textsuperscript{21}As is well known, the analogue of the 'fixed effects' estimator that treats $\eta_i$ and $\theta_i$ as fixed unknown parameters to be estimated, is in general inconsistent in the non-linear case due to the 'incidental parameters' problem [Neyman and Scott (1948)]. A conditional maximum likelihood estimator [Andersen (1970)] is not available here, since the non-linearity of the models due to the minimum condition violates the requirement that the likelihood contributions belong to the linear exponential family. See Chamberlain (1980)

\textsuperscript{22}A crucial assumption that the regressors and the random effects be independent is implicit here, with $f(\eta, \theta)$ not depending on the exogenous variables A Lagrange multiplier test of such assumptions in the context of disequilibrium models is presented in Hajivassiliou (1985)
Define the latent variables $A^* (= N^D - N^S)$ and $L^*$. Define the observables to be the realized level of new lending ($N$), the realized level of arrears ($A$), and a discrete variable indicating the event of a rescheduling ($\delta$). The three possible regimes are now characterized by

**Regime 1.** Excess supply:

$$A^* < 0 \Leftrightarrow N = N^D, \quad A = 0, \quad \delta = 0,$$

(A.4a)

**Regime 2.** Moderate excess demand:

$$0 < A^* < L^* \Leftrightarrow N = N^S, \quad A = A^*, \quad \delta = 0,$$

(A.4b)

**Regime 3.** Large excess demand:

$$A^* > L^* \Leftrightarrow \delta = 1.$$  

(A.4c)

To obtain the likelihood function for this problem, consider a country $i$ and evaluate probabilities conditional on the country-specific random effects. Denote $\sigma^2 = \sigma_D^2 + \sigma_S^2 - 2\rho\sigma_D\sigma_S$. Manipulating the joint normal distribution yields the conditional distributions

$$\begin{align*}
(A^* | N^D, \eta, \theta) &
\sim \mathcal{N}\left(D - S + \eta - \theta + \frac{\sigma_D^2 - \rho \sigma_D \rho_S}{\sigma_D^2} (N^D - (D + \eta)), \frac{\sigma_S^2}{\sigma_D^2} (1 - \rho^2)\right), \\
(N^S | A^*, \eta, \theta) &
\sim \mathcal{N}\left(S + \theta + \frac{\rho \sigma_D \rho_S - \sigma_S^2}{\sigma^2} (A^* + S - D + \theta - \eta), \frac{\sigma_D^2 \sigma_S^2}{\sigma^2} (1 - \rho^2)\right), \\
(N^D, N^S | \eta, \theta) &
\sim \mathcal{N}\left(D + \eta, S + \theta, \begin{bmatrix} \sigma_D^2 & \rho \sigma_D \rho_S \\ \rho \sigma_D \rho_S & \sigma_S^2 \end{bmatrix}\right),
\end{align*}$$

(A.5a)

(A.5b)

(A.5c)

and the marginal distribution

$$(A^* | \eta, \theta) \sim \mathcal{N}\left((D + \eta - S - \theta), \sigma^2\right).$$

(A.5d)
Hence, we obtain for each regime:

**Regime 1.** \( A = 0, \delta = 0, N = N^D: \)

\[
h_1 = P(A = 0, \delta = 0, N = N^D|\eta, \theta)
= P(A^* < N^D = N, \eta, \theta)P(N^D = N|\eta, \theta)
= \phi\left(\frac{\theta - \eta + S - D - (N - D - \eta)(1 - \rho(\sigma_D/\sigma_D))}{\sigma_D'(1 - \rho^2)}\right)
\times \frac{1}{\sigma_D} \phi\left(\frac{N - D - \eta}{\sigma_D}\right),
\] (A.6a)

**Regime 2.** \( A > 0, \delta = 0, N = N^S: \)

\[
h_2 = P(A > 0, \delta = 0, N = N^S|\eta, \theta)
= P(N^S = N|A, \eta, \theta)P(A^* > A, \eta, \theta)P(A|\eta, \theta)
= \frac{\sigma}{\sigma_D\sigma_D'(1 - \rho^2)}
\times \phi\left(\frac{N - S - \theta - ((\rho \sigma_D \sigma_D' - \sigma_D')/\sigma')(A + S - D + (\theta - \eta))}{\sigma_D\sigma_D'(1 - \rho^2)/\sigma'}\right)
\times e^{-B\lambda - \frac{1}{\sigma} \phi\left(\frac{A - D + S - \eta + \theta}{\sigma}\right)},
\] (A.6b)

**Regime 3.** \( \delta = 1: \)

\[
h_3 = P(\delta = 1)
= P(L^* < A^*)
= \int_0^\infty P(L^* < A^*, \eta, \theta)P(A^*|\eta, \theta)dA^*
= \phi\left(\frac{D - S + \eta - \theta}{\sigma}\right) - \phi\left(\frac{D - S + \eta + \theta}{\sigma} - B\sigma\right)
\times \exp(-B(D - S + \eta - \epsilon) - C + 0.5B^2\sigma^2).
\] (A.6c)
The joint likelihood of the $T_i$ observations on country $i$, conditional on the specific effects $\eta_i$ and $\theta_i$, is

$$H(\eta_i, \theta_i) = \prod_1 h_1(\eta_i, \theta_i) \prod_2 h_2(\eta_i, \theta_i) \prod_3 h_3(\eta_i, \theta_i),$$  \hspace{1cm} (A.7)$$

and therefore the $T_i$ observations on country $i$ have likelihood

$$\int_{-\infty}^{\infty} \int_{-\infty}^{\infty} H(\eta_i, \theta_i) f(\eta_i, \theta_i) d\eta_i d\theta_i = L_i.$$  \hspace{1cm} (A.8)$$

The maximum likelihood estimator is then obtained by maximizing $\sum_{i=1}^{I} \ln L_i$.23

An important issue is that the regressors appearing in section 3 include realizations of lagged dependent variables. This creates the initial conditions problem [Heckman (1981b) and Hajivassiliou (1986b)]. To briefly state the problem: let $y_{i,-1}$* be a latent variable, $y_i$ its observed counterpart, and $\theta$ a (vector) random effect. Since $y_{i,-1}$* is stochastically dependent upon the random effect $\theta$, so is $y_i$. Inconsistency will in general result if this dependence is neglected, since the true likelihood contribution for a country takes the form

$$\int_{-\infty}^{\infty} f(y_T, \ldots, y_1|y_0, \theta) f(y_0|\theta) f(\theta) d\theta,$$  \hspace{1cm} (A.9)$$

and conditioning on $y_0$ as an exogenous variable neglects the term $f(y_0|\theta)$. The approach adopted here, which is a modification of Heckman (1981b), assumes the same functional form (A.6a)-(A.6c) for $f(y_0|\theta)$ as for $f(y_i|y_{i-1}, \theta)$, $t > 1$, while letting the coefficients of the regressors be different for the $f(y_0|\theta)$ term.24

23 Each evaluation of the likelihood requires 1 numerical integrations over two variables, which can be prohibitively expensive. Hence we generalized a computationally efficient quadrature method [see Butler and Moffitt (1982) and Hajivassiliou (1984,1985)]. Because of the extreme computational burden involved, table 3 excludes variables that in table 1 were estimated with a totally insignificant coefficient. This should be viewed as purely a numerical optimization decision, and not a statistical one that would raise the usual pre-testing objections.

24 For computational simplicity, the method is implemented in three steps: first, consistent estimates of the parameters $\delta$ of the reduced-form equations of the dependent variables $y_0$ are obtained. Second, these are substituted in the $f(y_0|\theta)$ expression in (A.9) and the likelihood function is maximized over the structural parameters, thus providing consistent but inefficient estimates. We finally take a single Newton–Raphson step from the complete set of initial estimates using the first-order conditions of the full maximum likelihood problem. The resulting estimates would have the same asymptotic distribution as the full maximum likelihood ones, provided the assumption of same functional form for $f(y_0|\theta)$ and $f(y_i|y_{i-1}, \theta)$, $t \neq 1$, were correct. See Bhargava and Sargan (1983) for analogues of this approach in the linear regression case. In our non-linear models, the precise form of the $f(y_0|\theta)$ term is a non-trivial problem.
Data appendix

Abbreviations for data sources (computer tapes)

*BOP*  World Bank, *World Tables*, economic data sheet 2, balance of payments (1984),


All series consist of 823 country-year observations on 79 countries over the 1970–1982 period. This number is smaller than $79 \times 12 = 948$ because of missing values. All conversions between dollar and local currency values employed the period average exchange rate from IFS. Means and standard deviations appear in parentheses.

Dependent variables

*DVDEL* — *Presence of IMF support and/or request for a rescheduling* (0.153, 0.360)

IMF support is defined by an IMF standby agreement of second or higher tranche or use of the IMF Extended Fund Facility. Reschedulings include Paris Club, commercial banks, and aid-consortia renegotiations. This information was compiled from our own country-by-country investigations and from published and unpublished IMF sources. The date of rescheduling was selected to reflect the key economic developments precipitating the rescheduling.

*DNEW* — *Net new loans/Exports* (0.243, 0.402)

Net new loans equal end-of-period debt minus beginning-of-period debt. Debt refers to total disbursed or publicly guaranteed medium- and long-term debt plus total disbursed private medium- and long-term debt. Both variables were obtained from WDT in U.S. dollars. When private debt was not reported, it was set to zero, which may be an unsatisfactory practice for countries known to have significant and largely unreported debt obligations. The debt figures are normalized by exports of goods and nonfactor services, obtained from WT.

*ARR* — *Level of debt service obligations in arrears* (0.264, 1.46)

Figures were obtained from confidential files at the World Bank. Arrears on principal of smaller than 1 percent of disbursed debt and interest arrears of less than 0.1 percent of debt were treated as insignificant and hence set to zero.
Independent variables

**Debt service due / Exports** (0.159, 0.188)
For exports, see above. Debt service due is interest and amortization paid during the current period, including arrears outstanding at the end of the period.

**Real GNP / Capita** (0.683, 0.637)
GNP per capita in U.S. dollars was taken from WT and converted to real 1972 dollars using the U.S. GNP deflator from ERP.

**Growth rate of real GNP** (0.052, 0.006)
Calculated from the WT real GNP data.

**Imports / GDP** (0.352, 0.248)
Imports of goods and non-factor services obtained from WT and GDP from IFS. Both in local currency units.

**Reserves / Imports** (0.294, 0.262)
Total reserves minus gold in U.S. dollars from IFS. For imports, see above.

**Exports / GDP** (0.293, 0.228)
See above.

**Debt / Exports** (1.10, 1.09)
See above.

**Indicator for IMF support or rescheduling** (0.147, 0.355)
Lagged values of relevant indicators described under **DVDEL**.

**Indicator for presence of significant arrears** (0.228, 0.419)
Presence of significant arrears at \((t-1)\) (see **ARR**).

**Interest due / Exports** (0.043, 0.041)
See debt service due above.

**Principal due / Exports** (0.116, 0.161)
See debt service due above.

**IMF history** (0.766, 1.37)
Cumulated number of years since 1970 with IMF involvement.

**RSS history** (0.199, 0.620)
Cumulated count of reschedulings since 1970.

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