Journal of Development Economics 7 (1980) 3–21. © North-Holland Publishing Company

LDC PARTICIPATION IN INTERNATIONAL FINANCIAL MARKETS

Debt and Reserves

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Received September 1978, final version received March 1979

This paper analyzes LDC borrowing and reserve-holding behavior as part of a general equilibrium portfolio problem. Estimates of LDC debt and reserve demand and credit supply suggest that debt, along with reserves, serves a transactions role. Another finding is that most LDC borrowers are credit constrained. An analysis of LDC export behavior suggests that defaults are likely to be independent, uncorrelated phenomena.

1. Introduction

Increased participation by less developed countries in private international financial markets raises questions about the role of private capital markets in the international financial system. It has also generated fears about the possibility of widespread default. From 1967 to 1975 debt to private lenders of 86 country governments on which the World Bank reports [World Bank (1977)] has quadrupled. This category of debt rose from 23 to 50 billion dollars between 1972 and 1975. The debt for the largest LDC borrowers is given in table 1, along with their corresponding reserve holdings. The total debt of these countries slightly exceeds their total reserves, although individual countries exhibit marked discrepancies in their debt and reserve positions.

This paper focuses on two aspects of LDC borrowing from private sources. First, we examine the interaction of such borrowing with reserve holding.[1] Second, we analyze whether defaults, if they occur, are likely to occur singly or in groups.

In section 2, we present a theoretical analysis of borrowing and reserve holding behavior. Both types of behavior represent part of an overall

[1]Considerable research has focused on the behavior of LDC governments as holders of international monetary reserves. Williamson (1973) provides a survey. Relatively little analysis has been directed toward the borrowing behavior of these governments, however. [Frank and Cline (1971), Feder and Just (1977a, b), and Eaton and Gersovitz (1979) provide examples]. Furthermore, none, to our knowledge, considers borrowing and reserve holding together as aspects of LDC international portfolio management.

Table 1
Total private debt including undisbursed exceeding one billion dollars (1974) and corresponding reserves (millions of U.S. dollars).[a]

	Debt	Reserves		Debt	Reserves
Mexico	7114	1395	Chile	1823	102
Brazil	6710	5272	Zaire	1749	140
Algeria	4072	1689	Spain	1748	6485
Korea (S.)	3153	1056	Peru	1729	968
Indonesia	2859	1492	Taiwan	1440	1191
Argentina	2823	1315	Venezuela	1130	6513
Greece	2107	936	Malaysia	1065	1618
Iran	1907	8383			

[a]*Source:* World Bank (1977).

portfolio allocation problem. On the one hand, the LDC has a productive asset the return on which is risky and related to export performance. On the other hand, an LDC can hold an international asset, reserves, and/or undertake an international liability, debt.

Debt may provide a means of financing reserves. Or, as we have argued elsewhere [Eaton and Gersovitz (1979)], borrowing itself may directly perform a transactions function, serving to smooth domestic adsorption across periods in which export revenues vary. In the first case, debt and reserves are complements; increased borrowing in international capital markets will lead to reserve accumulation. In the second case, however, debt substitutes for the holding of reserves. An analogy is the use of credit cards by households as a substitute for cash and demand deposits.

Several important policy issues hinge on whether reserves and debt are substitutes or complements. For example, increased access to capital markets raises or lowers the demand for reserves by LDC's as reserves are complements or substitutes. Any assessment of the dollar overhang and the appropriate rate of SDR creation by the IMF depends on this relation between debt and reserves. Illiquidity among LDC's may have led to increased borrowing by LDC's, in which case increased distribution of SDR's to LDC's should reduce international indebtedness.

In considering the default issue, we emphasize the distinction between an economic unit in a national economy and a government. A government enjoys national sovereignty; the individual does not. Ruling out forceful intervention by other nations, a government can refuse to pay its creditors and maintain control of its domestic assets. An individual, by contrast, would be stripped of his assets in bankruptcy proceedings.

Our theoretical model emphasizes that a government cannot escape without penalty if it defaults. We assume that default results in an inability to borrow in private markets. This assumption is a stylized representation of the fact that default makes re-entry to the private capital markets extremely difficult.

To prevent borrowers from defaulting, lenders will attempt to impose credit ceilings. The more severe a penalty to a particular borrower is a credit embargo, the higher will be the credit ceiling allowed that country. Of course, an LDC may not wish to borrow up to its credit ceiling. These concepts are developed in detail in Eaton and Gersovitz (1979). In the present paper, we also argue that countries which are not credit constrained may have reserve holding behavior different from that of countries which are credit constrained. If, for instance, the constraint on borrowing is binding, reserves may have a higher opportunity cost.

Section 3 presents the econometric theory necessary for the joint estimation of the debt and reserves equations specified in section 2. We employ a maximum likelihood technique which hybridizes the techniques used in estimating switching regressions [Goldfeld and Quandt (1976)] and models in disequilibrium [Maddala and Nelson (1974)]. Since our approach has not been discussed previously, we derive the appropriate likelihood function explicitly.

Section 4 presents the econometric results for the debt and reserve-holding behavior of a cross-section of LDC's. The estimated equations largely confirm the theoretical structure and imply that debt and reserves are substitutes. Our estimation technique allows countries' debt to be either subject to a credit ceiling or not constrained, and we are able to estimate the probability that a country is constrained or unconstrained. We estimate a different reserve demand equation depending on whether a country is constrained or not.

Section 5 discusses whether LDC's are likely to default simultaneously or not. We consider the default decision to depend largely on export performance with default more likely to occur when export revenues are below average. To consider the probability of simultaneous, widespread default among LDC borrowers, we examine the correlation among LDC exports, giving special attention to the large borrowers of table 1. A concluding section summarizes the most important findings of the paper.

2. A three-asset model of debt and reserve demand, credit rationing and potential default

Consider a small country with a level of national wealth W. The country may hold as assets capital, which is risky, and reserves, which are not. It may also borrow in private international capital markets in amounts up to a credit ceiling $\bar{D}$. Debt to public lending institutions, P, is considered exogenous, determined in large part by political factors outside the scope of our model. Let K^*, R^* and D^* denote respectively the real demands for capital, reserves and private debts with demand functions

$$K^* = f^K(\sigma_x, M/Y, Y/N, g_y, r, P, W),$$
$$R^* = f^R(\sigma_x, M/Y, Y/N, g_y, r, P, W),$$
$$D^* = f^D(\sigma_x, M/Y, Y/N, g_y, r, P, W), \tag{2.1}$$

where Walras' Law implies

$$f^K + f^R - f^D = W + P. \tag{2.2}$$

The arguments of f^i are defined as follows:

σ_x = export variability,
M/Y = import share of GNP,
Y/N = real income per capita,
g_y = growth rate of real GNP per capita,
r = expected interest rate on debt,
P = debt to public lending institutions,
W = real wealth.

The last two arguments of the demand functions, P and W, capture scale effects. The first five are entered to reflect the relative returns on the different instruments. The variables σ_x and M/Y contribute to the demand for an asset to facilitate transactions [see Flanders (1971) and Frenkel (1974)]. A high growth rate and low level of per capita income imply a high rate of return on capital. Finally, a high level of r, of course, implies a high cost of debt. If each asset is a normal good then $f_1^R \geqq 0$, $f_2^R \geqq 0$, $f_3^K \geqq 0$, $f_4^K \leqq 0$ and $f_5^D \leqq 0$.

While (2.2) implies that

$$f_i^K + f_i^R - f_i^D = 0, \qquad i = 1, \ldots, 5, \tag{2.3}$$

in general one cannot infer the signs of all three derivatives from knowledge of one. Imposing the assumption of gross substitutability [Tobin (1969)] on the country's portfolio behavior implies a number of additional restrictions.

The assumption of gross substitutability, as it applies to assets, states that if the return on one asset rises, the demand for all other assets falls. Condition (2.3) implies, then, that the own effect of any rate change exceeds the cross effect. For example, if reserves provide the sole transactions instrument then an increase in σ_x, raising the demand for reserves, should cause demand for capital to fall and borrowing to increase.

If only reserves serve a transaction function then M/Y and σ_x proxy only for the own rate of return on reserves. Gross substitutability then implies that

$$0 \leqq f_1^D \leqq f_1^R, \qquad f_1^K \leqq 0, \tag{2.4}$$

$$0 \leqq f_2^D \leqq f_2^R, \qquad f_2^K \leqq 0, \tag{2.5}$$

$$0 \geqq f_3^D \geqq f_3^K, \qquad f_3^R \geqq 0, \tag{2.6}$$

$$0 \leqq f_4^D \leqq f_4^K, \qquad f_4^R \leqq 0, \tag{2.7}$$

$$f_5^D \leqq f_5^R \leqq 0, \qquad f_5^D \leqq f_5^K \leqq 0. \tag{2.8}$$

If debt directly facilitates transactions, replacing reserves, then restrictions (2.4), (2.5) and (2.8) are no longer implied. Specifically, one may obtain

$$f_1^D \geqq f_1^R \geqq 0, \tag{2.4'}$$

$$f_2^D \geqq f_2^R \geqq 0, \tag{2.5'}$$

$$f_5^R \geqq 0. \tag{2.8'}$$

Furthermore, since debt also serves the Fisherian role of transforming future income into present consumption one may find

$$f_3^D \geqq f_3^K \geqq 0. \tag{2.6'}$$

If public debt P is simply providing additional resources for investment in capital and reserves then as long as R and K are normal and D inferior,

$$f_6^K \geqq 0, \tag{2.9}$$

$$f_6^R \geqq 0, \tag{2.10}$$

$$f_6^D \leqq 0. \tag{2.11}$$

If, however, public debt, like private debt, serves directly as a transactions medium then

$$f_6^R \leqq 0 \tag{2.10'}$$

is not precluded.

If the demand for debt, D^*, falls short of the credit ceiling $\bar{D}$, D^*, R^* and K^* represent the actual allocation of wealth. If, however, $D^* \geqq \bar{D}$ then debt is constrained at $\bar{D}$, the credit ceiling. The borrower's portfolio problem is reduced to one of allocating $W+P+\bar{D}$ between capital and reserves. Denote the demand functions in the constrained case as

$$\begin{aligned} \bar{K}^* &= \bar{f}^K(\sigma_x, M/Y, Y/N, g_y, \bar{D}, P, W), \\ \bar{R}^* &= \bar{f}^R(\sigma_x, M/Y, Y/N, g_y, \bar{D}, P, W). \end{aligned} \tag{2.12}$$

We anticipate that the derivatives of $\bar{f}^R$ with respect to σ_x, M/Y, Y/N, g_y and W are of the same sign as those of f^R. In addition, if debt is serving solely to finance reserves and capital we expect

$$\bar{f}^R_5 \geqq 0, \qquad \bar{f}^R_6 \geqq 0. \tag{2.13}$$

If, however, debt serves as a transactions medium, we cannot preclude that a high level of indebtedness to private and public creditors reduces the demand for reserves, that is

$$\bar{f}^R_5 \leqq 0, \qquad \bar{f}^R_6 \leqq 0. \tag{2.14}$$

Consider now the lender's problem of establishing a credit ceiling $\bar{D}$. We specify borrower's utility as a function $U(W, \bar{D}, Z)$ of wealth, the credit ceiling, and a vector Z of other variables. U may be thought of as a dynamic programming value function, with W a state variable. We assume that U is twice-differentiable and that $U_1 > 0$, $U_{11} \leqq 0$, $U_2 \geqq 0$. In the event of default the borrower augments his wealth by an amount D where D denotes actual debt. We assume that the borrower also suffers the penalty of a credit embargo; henceforth $\bar{D}=0$. Default becomes optimal, then, when

$$U(W+D, 0, Z) \geqq U(W, \bar{D}, Z), \tag{2.15}$$

where $\bar{D}$ represents the borrowers *previous* credit ceiling.

Competitive lenders will impose a credit ceiling $\bar{D}$ to preclude condition (2.15) from obtaining with probability in excess of that accounted for in the risk premium charged on debt. The level of $\bar{D}$ will depend positively on the value to the borrower of continued access to credit markets. If debt performs a transactions role, a country with high transactions needs (proxied by σ_x and M/Y) will be most damaged by a credit embargo and will therefore sustain a high level of debt ($\bar{D}$) without defaulting.[2]

[2]Eaton and Gersovitz (1979) provide a more formal discussion of the determination of the credit ceiling.

Finally, borrowers may interpret a high level of indebtedness to public institutions as indicative of creditworthiness. Private lenders may regard these organizations as lenders of last resort if insolvency arises. Further, such institutions may have an advantage in imposing penalties in the event of default, raising the cost of default to the borrower.

The estimation of this model is complicated by the distinction between countries subject to a credit ceiling and those which are not. We next turn to an econometric methodology which permits estimation without information on which countries belong to which regime.

3. Joint maximum likelihood estimation of international indebtedness and reserve demand with potential credit rationing

Two implications of the analysis of the previous section are: (1) that the observed level of international indebtedness is given by the minimum of the borrower's demand for debt and the credit ceiling imposed by lenders and (2) that the presence of a binding credit ceiling may alter the borrower's demand function for reserves. We may state these implications in the following set of equations:

$$D_{1i} = X_i^{11}\beta_1 + u_{1i}, \tag{3.1}$$

$$D_{2i} = X_i^{12}\beta_2 + u_{2i}, \tag{3.2}$$

$$D_i = \min(D_{1i}, D_{2i}), \tag{3.3}$$

$$R_i = R_{1i} = X_i^{21}\gamma_1 + v_{1i} \quad \text{if} \quad D_{2i} \geqq D_{1i}, \tag{3.4}$$

$$= R_{2i} = X_i^{22}\gamma_2 + v_{2i} \quad \text{if} \quad D_{2i} < D_{1i}. \tag{3.5}$$

Here D_{1i}, D_{2i} and D_i denote, respectively, the demand for debt, D^*, the credit ceiling, $\bar{D}$, and the actual debt of country i. R_{1i} is the demand for reserves when the credit constraint is not binding, R^*, while R_{2i} is reserve demand in the constrained case, $\bar{R}^*$, and R_i the actual holding of reserves. X^{1j} is the vector of arguments of the debt demand $(j=1)$ and debt supply $(j=2)$ equations; X^{2j} is the vector of arguments of the reserve demand equations in the unconstrained $(j=1)$ and constrained $(j=2)$ cases. The vector β_1 denotes the coefficients of the debt demand equation, β_2 those of the credit ceiling equation, and γ_1 and γ_2 the coefficients of the reserve demand equations for the unconstrained and constrained cases respectively. The residuals of the equations are denoted u_{1i}, u_{2i}, v_{1i} and v_{2i}. Our task is to obtain maximum likelihood (ML) estimates of β_1, β_2, γ_1 and γ_2 and to determine the probability that an individual borrower is credit constrained.

The estimation of eqs. (3.1), (3.2) and (3.3) poses a classic problem of estimating markets in disequilibrium. ML techniques for this problem are discussed by Maddala and Nelson (1974) and Quandt (1977). Estimation of (3.4) and (3.5) constitutes a switching regressions problem of the type discussed by Goldfeld and Quandt (1976) among others. The switch between regimes is, in this case, determined by (3.3). The estimation problem of our complete model requires the combination of a disequilibrium with a switching regressions model. In this section we derive the likelihood function which is maximized to obtain the parameter estimates. Section 4 contains a discussion of our results.

We make the following assumptions about the distributions of the random variables u_{1i}, u_{2i}, v_{1i} and v_{2i}:

(i) The random variables are independently, normally distributed with zero mean and variances $\sigma_{u_1}^2$, $\sigma_{u_2}^2$, $\sigma_{v_1}^2$ and $\sigma_{v_2}^2$, respectively.
(ii) The covariance between any pair is zero.
(iii) $\sigma_{u_1}=\sigma_{u_2}=\sigma_u$.
(iv) $\sigma_{v_1}=\sigma_{v_2}=\sigma_v$.

Conditions (iii) and (iv) are imposed to ensure that the likelihood function is always bounded. [See Quandt (1977) for a discussion of this problem.]

Denote the joint probability density of D_i and R_i conditional on the X_i as

$$h(D_i, R_i \mid X_i). \tag{3.6}$$

Since u_i and v_i are independent for $i=1,2$ we may decompose h as follows:

$$h(D_i, R_i \mid X_i)=f(D_i \mid X_i)\cdot g(R_i \mid X_i). \tag{3.7}$$

Define the density of D_{ji} given X_i^{1j},

$$f_j(D_{ji} \mid X_i)=(2\pi\sigma_u^2)^{-\frac{1}{2}}\exp(u_{ji}^2/2\sigma_u^2), \tag{3.8}$$

where

$$u_{ji}=D_{ji}-X_i^{1j}\beta_j, \qquad j=1,2.$$

Then

$$F_j(D \mid X_i)\equiv 1-\int_0^D f_j(Q \mid X_i^{1j})\,\mathrm{d}Q \tag{3.9}$$

denotes the probability that $D_{ji}\geqq D$. We may thus write the density of D_i conditional on X_i as

$$f(D_i \mid X_i)=f_1F_2+f_2F_1, \tag{3.10}$$

that is, the sum of the densities given D_i, f_1 and f_2, weighted by F_2 and F_1 respectively. For a full derivation of (3.10) see Maddala and Nelson (1974) or Quandt (1977).

The probability, given D_i and X_i, that $D_i = D_{1i}$ is given by

$$P(D_i, X_i) = f_1 F_2 (f_1 F_2 + f_2 F_1)^{-1} \tag{3.11}$$

[see Gersovitz (1978)]. The probability that $D_i = D_{2i}$, given X_i, is simply $1 - P(D_i, X_i)$.

Defining the density of R_{ji} given X_i as

$$g_j(R_{ji} \mid X_i) = (2\pi\sigma_v^2)^{-\frac{1}{2}} \exp(-v_{ji}^2/2\sigma_v^2), \tag{3.12}$$

where

$$v_{ji} = R_{ji} - X_i^{2j}\gamma_j, \qquad j = 1, 2,$$

the density of R_i given X_i is simply

$$g(R_i \mid X_i) = P \cdot g_1(R_{1i} \mid X_i^{21}) + (1-P) \cdot g_2(R_{2i} \mid X_i^{22}). \tag{3.13}$$

Given N observations on D_i, R_i and the X_i we may define the likelihood function L as

$$L \equiv \prod_{i=1}^{N} h(D_i, R_i \mid X_i). \tag{3.14}$$

Thus $\mathscr{L}$, the log-likelihood function, is given by

$$\mathscr{L} = \sum_{i=1}^{N} \{\ln(f_1 F_2 + f_2 F_1) + \ln[P g_1 + (1-P) g_2]\}. \tag{3.15}$$

Our estimates of β_1, β_2, γ_1 and γ_2 maximize $\mathscr{L}$.

4. Empirical results

We estimated eqs. (3.1) through (3.5) using a cross-section of 45 LDC borrowers in two years, 1970 and 1974. Table 4 provides a list of these countries and the years for which each is included. Our dependent variables, D and R, represent the public debt of LDC's to private creditors and LDC holding of international reserves respectively, each variable in per capita terms. Both are expressed in terms of 1970 U.S. dollars and enter in natural logarithmic form. The credit ceiling, demand for debt and demand for reserves are specified as functions of the percentage variability of exports (σ_x), the share of imports in GNP (M/Y), the average growth rate of per capita income (g_y), the natural logarithms of total real GNP per capita (Y/N), total population (N) and the real level of public debt to private creditors (P) expressed in per capita terms, and a dummy variable (T) equal to 0 in 1970 and 1 in 1974. The variable D is also included as an explanatory variable in the reserve demand equation for the *constrained* case. Appendix A provides exact definitions of these variables and their sources.

The variable N is entered to capture scale effects in the demand functions. Size may also affect the credit ceiling positively. Economies of scale in monitoring creditworthiness may make large borrowers more attractive. Furthermore, large borrowers are frequently more politically important. Lenders may feel that developed-country governments will take a more active role in forestalling default by large borrowers.

In competitive loan markets, if lenders are risk-neutral or if default risk is diversifiable, the *expected* interest rate r is equal for all borrowers in *each year*. For this reason we do not include r as an explanatory variable. The expected interest rate should be distinguished from the rate actually charged, which exceeds the safe, market interest rate by an amount determined by the lender's expectation of default.[3] As long as the borrower's and lender's expectations coincide, the return the lender expects to realize, which should equal the market rate, should also equal the rate the borrower expects to pay. We use the dummy variable T to capture differences in credit market conditions between 1970 and 1974, along with shifts in the demand for debt and reserves.

Values of the vectors of coefficients β_1, β_2, γ_1 and γ_2 maximizing (3.15) were obtained using the GRADX option of the GQOPT program at Princeton University based on the method of Goldfeld, Quandt and Trotter (1966) with a convergence accuracy of 10^{-7}. All calculations were done in double precision FORTRAN. Estimation results appear in tables 2 and 3.

The results support the hypothesis that debt is a substitute for reserves as a transactions medium. For one thing, the coefficients of P in both reserve demand equations and the coefficient of D in the $\bar{R}^*$ equation are all negative. If a country is credit constrained its reserve demand falls when its access to credit rises. For another, a high σ_x significantly increases credit demand and credit availability, suggesting that credit does indeed serve a transactions role; a country with unstable exports is less likely to sacrifice access to capital markets if credit is used to smooth consumption across periods of varying income.

Turning to the income and scale variables, note that reserves and credit availability all tend to rise with per capita income, while demand for debt is

[3] Feder and Just (1977b) examine the determinants of this mark up.

Table 2
Public indebtedness of LDC's to private creditors.[a]

	D^* (demand) equation		$\bar{D}$ (supply) equation	
Variable	Coefficient	MLE/SE[b]	Coefficient	MLE/SE[b]
Constant	−6.81	—	0.34	—
σ_x	1.73	(0.74)	7.05	(3.35)
M/Y	3.84	(2.32)	1.16	(0.93)
Y/N	0.29	(1.07)	1.42	(6.10)
N	0.71	(3.61)	−0.32	(2.25)
g_y	0.028	(0.55)	−0.046	(0.96)
P	1.23	(4.08)	0.169	(0.64)
T	−0.17	(0.47)	−0.56	(1.96)

[a]Value of the logarithm of the likelihood = −146. Number of observation = 81.
[b]MLE/SE: Maximum likelihood estimate divided by standard error is asymptotically t.

Table 3
Reserve demand by LDC's.[a]

	R^* (unconstrained regime)		$\bar{R}^*$ (constrained regime)	
Variable	Coefficient	MLE/SE[b]	Coefficient	MLE/SE[b]
Constant	10.34		4.45	—
σ_x	3.84	(4.04)	3.45	(3.85)
M/Y	−0.29	(0.38)	1.13	(2.02)
Y/N	1.44	(11.67)	1.21	(10.53)
N	−0.51	(5.54)	−0.31	(4.69)
g_y	0.0011	(0.05)	0.11	(5.29)
P	−1.2	(8.96)	−0.43	(3.05)
T	0.35	(2.02)	−0.08	(0.65)
D		—	−0.10	(1.58)

[a]For notes, see table 2 above.

unaffected. Richer countries hold more reserves but do not desire to borrow more than poorer countries. Holding Y/N constant, population has a significantly positive effect on both debt demand and debt supply and a significantly negative effect on reserve demand. Large countries appear to rely on debt more and on reserves less. Finally, the coefficients of T imply that the demand for debt and reserves did not rise significantly between 1970 and 1974, while credit availability actually diminished.

A final aspect of our analysis is the estimation of the probabilities that individual countries are subject to credit constraints. Our estimates of these probabilities based on eq. (3.11) appear in table 4. Fifty-six of 81 observations are classified as constrained with probability greater than 0.5, suggesting that credit rationing was an important aspect of lending during this period. Of the major borrowers listed in table 1 which are also in our sample, only Argentina and Greece appear as unconstrained. The unconstrained group (Argentina, Ecuador, Greece, Guatemala, Jamaica, Panama, Paraguay, Portugal, and Trinidad/Tobago in both years; Costa Rica, El Salvador, Nicaragua and Togo in 1970; Gabon, Sierra Leone and Zambia in 1974) includes, with some notable exceptions, countries characterized by successful export performance and reasonable political stability during the period in question.

5. The correlation of LDC export performance

A country will default when the benefit of relief from debt-service obligations exceeds the penalties of debt repudiation. In a deterministic world informed, rational investors will impose debt ceilings precluding default. Investors cannot always know with certainty, however, that a borrower will choose to repay.

Other things equal, a country will be most tempted to default when the marginal utility of income is high. Since export revenue provides a major source of income variation, default seems most likely in periods of poor export performance. We have argued above that countries which anticipate high export variability in the future are less likely to default so as to maintain access to credit markets. However, default, if it occurs at all, is most likely in periods when export revenue is low relative to trend and hence the marginal utility of income high. We have illustrated this point more formally elsewhere in a stochastic model of borrowing and default [Eaton and Gersovitz (1979)].

In this section, we investigate whether LDC export performance has been highly correlated. If LDC exports are highly correlated, many LDC's might be expected to default simultaneously. Furthermore, their common interests at this time might help to give them a political cohesion which could make default less costly. On the other hand, if the export performance of different LDC's is independent, defaults or problem cases might be more frequent but, at the same time, more easily absorbed by the international financial system. If the conditions precipitating defaults are independent, there is potential for diversification among borrowers.

For each LDC which appears in table 4 we regressed the natural logarithm of real U.S. dollar exports, as taken from the IMF, *International Financial Statistics*, on a constant and time for the period 1963–1976. An unexpected export performance in any year is defined as the corresponding error term of this equation. This error term is unit free since the logarithmic

Table 4
Countries in the sample and the probability of the supply constrained ($\bar{D}$) regime.

Country	Year	Probability
Argentina	1970	0.40
	1974	0.49
Bolivia	1970	0.62
	1974	0.65
Brazil	1970	0.89
	1974	0.88
Burma	1974	0.75
Cameroon	1970	0.72
	1974	0.70
Chile	1970	0.64
	1974	0.58
Colombia	1970	0.92
	1974	0.93
Costa Rica	1970	0.31
	1974	0.64
Dominican Republic	1974	0.71
Ecuador	1970	0.38
	1974	0.27
El Salvador	1970	0.16
	1974	0.60
Ethiopia	1970	0.73
	1974	0.96
Gabon	1974	0.12
Greece	1970	0.33
	1974	0.35
Guatemala	1970	0.23
	1974	0.28
Honduras	1974	0.93
India	1970	1.00
	1974	1.00
Indonesia	1974	1.00
Iran	1970	0.81
	1974	0.62
Ivory Coast	1970	0.57
	1974	0.70
Jamaica	1970	0.19
	1974	0.29
Kenya	1970	0.91
	1974	1.00
Korea	1970	0.83
	1974	0.98
Malawi	1970	0.81
	1974	0.96
Malaysia	1970	0.91
	1974	0.90
Mexico	1970	0.69
	1974	0.72
Morocco	1970	0.90
	1974	0.94
Nicaragua	1970	0.25
	1974	0.57
Nigeria	1974	1.00
Panama	1970	0.28
	1974	0.48
Paraguay	1970	0.20
	1974	0.38
Peru	1970	0.52
	1974	0.62
Philippines	1970	0.71
	1974	0.95
Portugal	1970	0.40
	1974	0.30
Sierra Leone	1974	0.49
Spain	1970	0.51
	1974	0.54
Taiwan	1970	0.88
	1974	0.97
Thailand	1970	0.95
	1974	1.00
Togo	1970	0.22
Trinidad/Tobago	1970	0.06
	1974	0.00
Tunisia	1970	0.76
	1974	0.90
Turkey	1970	0.99
	1974	1.00
Yugoslavia	1970	0.80
	1974	0.97
Zaire	1970	0.59
	1974	0.77
Zambia	1974	0.49

specification implies that the error represents the *percentage* by which exports deviated from trend.

One method of analyzing these data would be to construct a structural model of off-trend export performance, requiring an analysis of both demand and supply conditions for the exports of each LDC. It would then be necessary to simulate the independent variables to explain the covariability of each LDC's exports with those of other LDC's. A myriad of factors would need to be considered: whether the various LDC export goods are substitutes or complements in consumption, with which goods produced in industrialized countries these exports compete, whether supply conditions in different LDC's vary together or in an offsetting fashion. An extremely difficult task under any circumstances, given only 14 observations on each country's exports it is impossible.

Instead, we employ two multivariate methods, factor-analysis (FA) and multidimensional scaling (MDS) to analyze LDC export instability. FA is well-known to economists and has been used to analyze topics in economic development [Adelman and Morris (1967)]. We have 14 observations on off-trend exports for each of 45 LDC's. To understand how much independence there is in this set of 45 variables, we calculated the 12 possible factors for this data set. (There are 12 rather than 14 factors since ordinary least squares produces only $T-2$ independent residuals from T observations.) The percentages of variability of off-trend exports accounted for by each of these factors are shown in table 5. There appears to be considerable diversity in LDC export experience since a large number of factors are required to account for most of the variation.

MDS is a method which has only recently been adopted in economics [Maital (1978)] and requires some description. Consider the $k \times k$ matrix

Table 5
Percent of variation explained by factors.

Factor	Percent variation
1	42.9
2	18.8
3	11.6
4	8.6
5	5.2
6	3.6
7	3.0
8	2.4
9	1.8
10	1.0
11	0.6
12	0.5

with typical element r_{ij} being the correlation coefficient between the ith and jth LDC's off-trend exports. This matrix provides much information on the covariability of LDC exports, yet, unless the relationships were very stark, such a matrix would be difficult to interpret. For instance, it would be very hard to group countries by the similarity of their performance.

MDS attempts to make the interpretation of the correlation matrix easier by providing a pictorial representation of the interrelationships embodied in the matrix. Consider a plot of each of k points in two-dimensional space. Each point represents one of the k LDC's. Scaling attempts to plot the k points so that the distance between points corresponds to the relative correlation of the associated countries' exports. Thus, if one pair of points is closer than another pair of points, the exports of the first pair of LDC's should be more highly correlated than the exports of the second pair. It is then possible to find clusters of points which imply groups of countries with similar export performances.

It is not, in general, possible to ensure that relative distances always mirror the relative correlations. To the extent that a perfect mapping of the points is not possible, MDS minimizes an index which measures the discrepancies between the relative distances and correlations. Further details on the method are available in Maital (1978) and Kruskal (1964).

Using the correlations for the 45 countries listed in table 4 yields the scaling diagram of fig. 1. Two distinct clusters of countries emerge with several rather small groupings elsewhere. This pattern suggests the opportunity for some, but not unlimited, diversification through the lending to countries in different groups. Distances in the diagram are relative so the axes are not labelled. To give some feeling for the underlying correlations between the exports of different countries, we record the following pairs of countries and their correlation: Nicaragua and Spain, -0.76; Nicaragua and Togo, -0.01; Nicaragua and Turkey, 0.31; Kenya and Malaysia, -0.26.

Because banks in the different industrial countries tend to concentrate their lending in different geographical zones, it is interesting to note that there are no discernible geographical groupings. For instance, the Latin American countries do not all group together. The superficial inference that this geographical concentration might preclude the opportunity for diversification is not supported. Similarly, the large borrowers of table 1 do not cluster together so that they are as unlikely as any other group of countries to be in trouble simultaneously.

FA and MDS provide a means of determining the extent to which the export performances of individual LDC's are correlated. The assessment of the risk involved in lending to any particular country, however, depends on the extent to which that country's performance is correlated with aggregate performance. Increased lending to a country whose exports are highly positively correlated with the average debtor's increases the riskiness of the

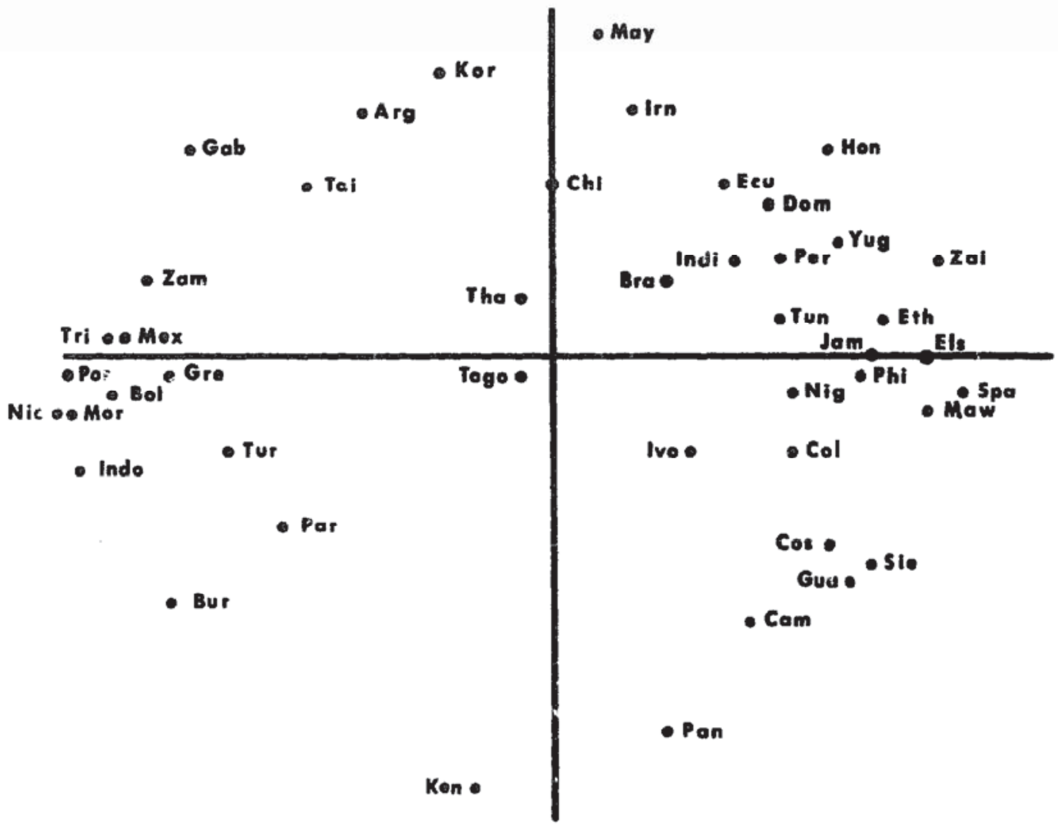

Fig. 1. Multidimensional scaling of exports.

overall portfolio. Conversely, risk falls when a loan is made to a country with exports which are negatively correlated with the average.

To distinguish those countries which contribute to overall risk from those which reduce it, we estimated the equation

$$y_{it} = \alpha_i + \beta_i x_t, \tag{5.1}$$

where y_{it} represents the percentage deviation from trend of country i's exports in year t and x_t denotes the percentage deviation from trend of aggregate exports in our sample. The average value of β is one; $\beta > 1$ implies greater than average risk and $\beta < 1$ the converse. Assessment of risk in terms of β is similar to Sharpe's (1964) 'β analysis' to isolate the market risk from the individual risk of corporate stocks.

Our estimates of β_i appear in table 6. Fourteen countries out of 45 have export patterns which exaggerate the total while 13 are countercyclical. Of the 12 major borrowers listed in table 1 which also appear in our sample, exports from Argentina, Brazil, Indonesia and Malaysia magnify world

Table 6
Estimates of β_i.

Argentina	1.64	Malawi	−0.77
Bolivia	0.0	Malaysia	1.19
Brazil	1.03	Mexico	0.36
Burma	1.89	Morocco	1.23
Cameroon	0.14	Nicaragua	0.11
Chile	−0.04	Nigeria	3.06
Colombia	0.58	Panama	−1.62
Costa Rica	−0.54	Paraguay	0.98
Dominican Republic	0.52	Peru	−0.57
Ecuador	2.34	Philippines	0.90
El Salvador	−0.22	Portugal	0.12
Ethiopia	1.03	Sierra Leone	−0.18
Gabon	0.49	Spain	0.05
Greece	0.21	Taiwan	0.99
Guatemala	−0.11	Thailand	1.37
Honduras	−1.14	Togo	0.60
India	−0.26	Trinidad	1.03
Indonesia	2.33	Tunisia	1.47
Iran	1.59	Turkey	1.13
Ivory Coast	0.28	Yugoslavia	−0.11
Jamaica	−0.65	Zaire	0.38
Kenya	0.55	Zambia	−0.08
Korea	0.25		

fluctuations while only Peru and to a small extent Chile have countercyclical exports. On the other hand, of the 16 countries whose debt levels are classified at some point as demand determined, 7 have exports which are countercyclical while Argentina's, Ecuador's and Trinidad's export patterns amplify world fluctuations. We conclude that the exports of the major borrowers do seem correlated with total LDC exports while the unconstrained borrowers are often atypical.

6. Conclusion

This paper has addressed two major issues arising from the LDC debt problem: the relationship between LDC borrowing and reserve demand and the likelihood of widespread default. We summarize our major conclusions as follows:

(1) Borrowing from both public and private sources has served a transactions role which has diminished the demand for reserves. This development is analogous, in many ways, to the use of credit cards as a substitute for *M1* at the domestic, household level.

(2) The maximum amount of credit which private lenders are willing to

extend depends positively on export variability and per capita income and negatively on population.

(3) A majority of borrowers are constrained in the amount they can borrow by credit ceilings. The unconstrained countries are characterized, on the whole, by strong export performance.

(4) The export performances of individual LDC's are largely uncorrelated, suggesting that defaults are likely to occur independently rather than in groups.

(5) To the extent that total LDC exports do in fact move together the large borrowers' exports are correlated with the overall LDC export performance.

The short history of LDC participation in private credit markets precludes a rigorous econometric examination of borrowing by individual LDC's. As more data become available, however, our conclusions can be examined by a time-series analysis of individual country experience.

Appendix A: Definition of variable values

D = Per capita public debt (including undisbursed) with maturity of one year or more to suppliers, financial markets and other private creditors (World Bank, *World Debt Tables*) given in U.S. current dollars divided by the U.S. GNP deflator (Federal Reserve Board, *Bulletin*). The variable was then logged.

R = Per capita reserves in current U.S. dollars (IMF, *International Financial Statistics*) divided by the U.S. GNP deflator (Federal Reserve Board, *Bulletin*). Logged.

σ_x = For the periods 1964–1970 and 1968–1974 for each country, a regression of the natural logarithm of real exports (IMF, *International Financial Statistics*) on a constant and time was performed. σ_x was defined as the standard error of this regression.

M/Y = Ratio of imports to GNP (IMF, *International Financial Statistics*).

N = Total population (World Bank, *World Bank Atlas*). Logged.

Y/N = Current U.S. dollar GNP per capita (World Bank, *World Tables*) divided by the U.S. GNP deflator (Federal Reserve Board, *Bulletin*). Logged.

g_y = For the periods 1964–1970 and 1968–1974 for each country, a regression of the natural logarithm of real GNP (IMF, *International Financial Statistics*) on a constant and time was performed. g_y was defined as the coefficient of time less the corresponding population growth rate.

P = Per capita public debt (including undisbursed) to international organizations, DAC governments and other (non-communist) governments (World Bank, *World Debt Tables*) given in U.S. current dollars divided by the U.S. GNP deflator (Federal Reserve Board, *Bulletin*). The variable was then logged.

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