IMF Staff Papers
Vol. 53, No. 2

Volatility and the Debt-Intolerance Paradox

LUIS CATÃO AND SANDEEP KAPUR*

A striking feature of sovereign lending is that many countries with moderate debt-to-income ratios systematically face higher spreads and more stringent borrowing constraints than other countries with far higher debt ratios. Earlier research has rationalized the phenomenon in terms of sovereign reputation and countries' distinct credit histories. This paper provides theoretical and empirical evidence to show that differences in underlying macroeconomic volatility are key. While volatility increases the need for international borrowing to help smooth domestic consumption, the ability to borrow is constrained by the higher default risk that volatility engenders. [JEL C23, F34]

It is a well-documented empirical regularity that developing countries typically face an upward sloping supply schedule for international debt, and may be altogether excluded from international capital markets at times (Díaz-Alejandro, 1984; Eichengreen and Lindert, 1989; and Sachs, 1989). In a recent paper, Reinhart, Rogoff, and Savastano (2003; RRS henceforth) take this evidence one step further. Combining macroeconomic data for the post-1970 period with information about sovereigns' credit histories since the early nineteenth century, they argue that an important subgroup of middle-income countries or "emerging markets" have been *systematically* afflicted by what they call "debt intolerance." That is, even though their external debt-to-GDP ratios are moderate by international standards and

*Luis Catão is a Senior Economist, IMF Research Department, and Sandeep Kapur is an Associate Professor, Birkbeck College, University of London. We thank Michael Bordo, Gian Maria Milesi-Ferretti, Richard Portes, Carmen Reinhart, an anonymous referee, as well as panel participants of the 2005 meetings of the Latin American and Caribbean Economic Society (LACEA) for comments on earlier drafts. We are also grateful to Tamim Bayoumi and Patrick Guggenberger for helpful discussions, to Katia Berruetta for editorial assistance, and to the department of economics at UCLA for their hospitality during Luis Catão's visit to that institution, when much of this paper was written.

substantially lower than those of several high-income countries, these economies are perceived as riskier and unable to tolerate as much debt. Simply put, their sovereign risk appears to be out of proportion to the size of the respective debt burdens.

To explain this phenomenon, RRS invoke history. Virtually all of these countries have tarnished credit histories, with several of them having defaulted a few times on their public debts. To the extent that those that have defaulted once or more are likely to do so again, the market threshold of what can be considered "safe" borrowing levels for these countries tends to be lower.[1] As a theoretical story, however, this argument raises three questions. The first is whether lenders have, in fact, systematically punished recalcitrant borrowers with higher spreads and more limited market access historically—an issue about which the empirical evidence has been mixed.[2] Second, one is left with the question of what caused serial defaulters to default in the first place. Third, one needs to explain how most of today's advanced economies—which have also defaulted several times in their histories—managed to graduate out of the debt-intolerant "club."

This paper advances a simple but arguably more fundamental explanation for the debt-intolerance phenomenon. We contend that the underlying high volatility of macroeconomic aggregates is a key driver of sovereign risk in developing countries. This volatility can stem from distinct sources, including long-rooted institutional arrangements that tend to foster time-inconsistent policies and procyclical fiscal outcomes, as well as from narrow commodity specialization that induces terms-of-trade (TOT) instability. We argue that this greater volatility is associated with higher default probability and, as a result, these countries face borrowing constraints at lower levels of indebtedness. To the extent that such volatility stems from structural and, hence, slowly evolving factors, the phenomenon can be fairly persistent, even if there is scope for these countries to gradually evolve out of this state. In this sense, we view the debt-intolerance phenomenon as another—and a so far relatively neglected—manifestation of macroeconomic volatility on developing country welfare. The evidence provided in this paper thus bridges a gap between the literature on sovereign debt and that on the adverse effects of macroeconomic volatility on growth and welfare (for example, Mendoza, 1995 and 1997; Ramey and Ramey, 1995; Agénor and Aizenman, 1998; Caballero, 2000; and Acemoglu and others, 2003).

---

[1]Lindert and Morton (1989) find that countries that defaulted over the 1820–1929 period were, on average, 69 percent more likely to default in the 1930s, and those that incurred arrears and concessionary reschedulings during 1940–79 were 70 percent more likely to default in the 1980s. The main shortcoming of these estimates, however, is that they are not conditioned by changes in countries' fundamentals. Estimates of credit risk transition probability matrices conditional on a variety of macroeconomic fundamentals are provided in Hu, Kiesel, and Perraudin (2002). Their estimation exercise, however, is limited to the post-1980 period.

[2]Looking at the interwar and early post–World War II comparisons of credit access to sovereigns with distinct repayment records, Jorgensen and Sachs (1989) find that international capital markets have done a fairly poor job in discriminating "bad" from "good" borrowers. In a similar vein, Eichengreen and Portes (1986) do not find clear-cut support for the hypothesis that well-behaved debtors in the interwar period that honored their debt obligations during the 1930s depression benefited from more favorable market access. Looking at data from between 1968 and 1981, Ozler (1993) finds that past repayment record is statistically significant in explaining differences among sovereign spreads across her sample of 26 developing countries.

As discussed below, the thrust of our argument does not imply that the relationship between income volatility and default risk is straightforward. On the one hand, greater income volatility suggests a higher probability of large negative income shocks that lead to “nonstrategic” or “excusable” default along the lines of a “capacity-to-pay” argument. On the other hand, Eaton and Gersovitz’s (1981) classic model suggests an alternative relationship in which default is punished by permanent exclusion from capital markets; because future exclusion is more costly for borrowers with more volatile incomes, their model suggests that greater volatility tends to *decrease* the likelihood of strategic default. Yet income volatility also affects the likelihood of default through other channels. First, volatility may affect the level of indebtedness that, in turn, tends to be positively related to default risk. Some models ignore this by assuming either that the level of indebtedness is exogenously given or that the borrower chooses to borrow as much as the lenders will allow (see, for instance, Grossman and Van Huyck, 1988; Grossman and Hahn, 1999; and Alfaro and Kanczuk, 2005). Second, volatility affects the terms on which lenders can borrow, with countries that have more volatile incomes often paying a higher risk premium. It is quite possible that countries that can access capital markets on less-than-advantageous terms care less about maintaining future access to these markets, so they may be more inclined to default in times of crises.

This paper aims to disentangle some of these complex effects in the context of a simple model and by presenting new econometric evidence on the roles of volatility, credit history, and other controls on default probabilities and borrowing capacity. In the model, the optimal level of debt trades off the benefit of borrowing in providing consumption insurance against bad output realization versus the cost of a higher borrowing spread. This spread is shown to be increasing on underlying macroeconomic volatility as well as (possibly) on a poorer credit history. Because greater volatility increases the risk premium for any given level of debt, this tends to dampen borrowing. Conversely, as borrowing is motivated by consumption smoothing, increased volatility increases the incentive to borrow. We find that whereas volatility may have an ambiguous effect on the optimal level of debt, the ex ante probability of default unambiguously increases in volatility.

Looking at the empirical evidence in light of this theoretical perspective, we examine the extent to which volatility and countries’ repayment histories explain default risk over and above other standard controls proposed in the literature. Logit estimates of default probabilities in a cross-country panel spanning the 1970–2001 period clearly indicate that output and TOT volatility are highly significant in explaining sovereign risk—a result that is strikingly robust to the inclusion of the various explanatory variables considered in previous studies. At the same time, our estimates show that once volatility variables are included in the regression, the credit history variable used by RRS is no longer statistically significant. This suggests that countries’ credit histories may be, at least in part, proxying for the effects of volatility on sovereign risk not contemplated in the RRS regressions.

We then turn to the issue of how volatility affects sovereign indebtedness. As noted above, a rise in volatility increases loan demand for consumption smoothing purposes, but it also has a supply deterrent effect through higher spreads that may become binding at times; thus, we consider a model that allows for the switch between the two regimes. The respective econometric results indicate that the supply effect predominates most of the time, so that the net effect of volatility on indebtedness tends to be negative. This, in turn, helps explain the second pillar of the debt-intolerance phenomenon documented by RRS—that is, why more volatile countries (which naturally tend to default more often) rarely manage to attain very high levels of sovereign debt relative to income. This explanation is arguably a more fundamental explanation for debt intolerance, in as much as it highlights a mechanism through which certain types of sovereigns default not only once but also repeatedly thereafter. This contrasts with the "virtuous circle" pattern often observed in countries with intrinsically less volatile TOT and income, which can attain higher indebtedness levels without incurring serial default.

I. Model

We assume that sovereign borrowing is motivated by the desire to smooth consumption in the face of domestic income shocks. The sovereign borrower can be viewed as a government that borrows to smooth its own consumption given volatile revenues, or one that borrows on behalf of its citizens to smooth their consumption given the variability of national income. Our benchmark model has two periods. In the first period, the sovereign chooses its level of borrowing; in the second period, after the realization of its random income, the sovereign chooses whether or not to repay its debt. If the debt is not fully repaid, the lender can impose sanctions that cause the borrower to lose a proportion of its period-2 output. We build on this standard framework (see Obstfeld and Rogoff, 1996, chapter 6) to develop the impact of volatility on sovereign risk and optimal borrowing.

We assume that funds borrowed by the sovereign are either held as central bank reserves or invested domestically; however, in each case, they yield the international risk-free interest rate. With debt $D > 0$ in period 1, total income gross of debt repayment in period 2 is

$$Y_2(D) = Y + \varepsilon + RD, \tag{1}$$

where $\bar{Y}$ is mean autarkic output, $\varepsilon \in [-\varepsilon_m, \varepsilon_m]$ is a random shock with zero mean, and R is the gross risk-free interest rate. The debt contract requires the sovereign to repay $R_L D$ in period 2. The spread between the contractual rate R_L and the risk-free rate R reflects country-specific default risk: the possibility that the sovereign may choose to renege on its repayment obligation.

Lenders have access to an enforcement technology. In the event of default, they can capture a fraction η of the borrower's period-2 income.[3] In this simple

[3]This simple parametrization of borrowers' losses associated with default has been advanced in Sachs (1984) and Sachs and Cohen (1985). Cohen (1992) provides measures of the relatively large output costs of default incurred by borrowers during the 1980s debt crisis, whereas Sturzenegger and Zettelmeyer (2005) provide recent evidence on how low lenders' effective recovery rates ("hair cuts") can be. To the extent that borrowers' costs do not automatically and fully translate into gains accrued by lenders, default events can entail significant deadweight losses. We show below how deadweight losses are incorporated into our model.

two-period context, it is rational for the sovereign to default if and only if the repayment obligation exceeds losses due to enforcement. Repayments are state-contingent:

$$P(\varepsilon, R_L, D) = \begin{Bmatrix} R_L D & \textit{for } \varepsilon \geq e \\ \eta[\bar{Y} + \varepsilon + RD] & \textit{for } \varepsilon < e \end{Bmatrix}, \tag{2}$$

where $e(R_L, D) \equiv \dfrac{[R_L - \eta R]D}{\eta} - \bar{Y}$.

Thus, there exists a critical value e, such that the borrower repays the debt if and only if the random shock $\varepsilon \geq e$. In others words, repayment is rational only for relatively high realizations of output.

Effects of Volatility on Loan Supply

Turning to the supply side of the loan market, we depart from the standard formulation (Sachs and Cohen, 1985; and Obstfeld and Rogoff, 1996) in which lenders can impose sanctions but do not capture any output. Nor do we assume, at the other extreme, that the capture technology is perfect. We allow for deadweight losses in that the lender's effective recovery is less than the defaulter's losses. We model this as follows.

Let the size of the default be given by the difference between the contractual repayment obligation $R_L D$ and actual repayments P:

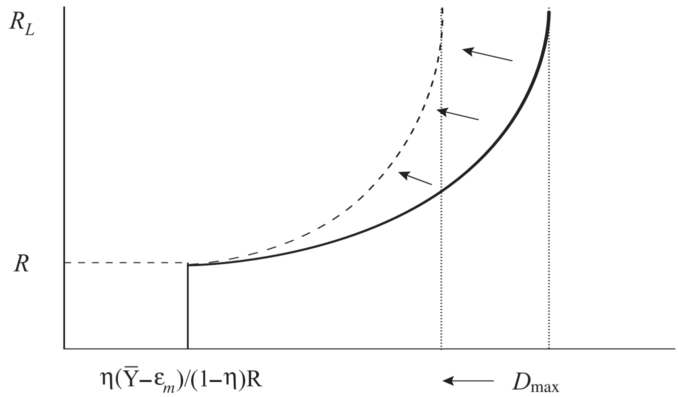
$$S(\varepsilon, D) = R_L D - P(\varepsilon, R_L, D). \tag{3}$$

In addition to the direct costs to lenders (which possibly include administrative, legal, and political costs), we assume that default involves a negative externality. For instance, default in one country may increase the risk of default by other borrowers through contagion effects. Such spillover costs create a wedge between repayments and the return to lenders. We assume that spillover is proportional to the size of the default: default of size S imposes a total cost $(1+q)S$ on the lender. The net return to the lender is given by the difference between contractual repayments and total default costs:

$$P^*(\varepsilon, R_L, D) = R_L D - (1+q)S(\varepsilon, D). \tag{4}$$

In keeping with the standard assumption in the literature, we consider a competitive market for international lending with risk-neutral lenders. This implies that lenders choose R_L to break even. However, the break-even interest rate varies with D as the level of indebtedness affects the default probability. When debt is low relative to mean income, the threat of capture precludes default, so the competitive contractual interest rate R_L coincides with the risk-free rate. At higher levels of debt, default becomes increasingly more likely. For the lender to break even, the interest

Figure 1. Effects of Volatility on Spreads and Borrowing Ceilings



rate spread $R_L(D) - R$ must increase with D, giving rise to the standard upward sloping supply curve for debt. This curve is truncated above some D_{max} because the required break-even interest rate would rise without bound with higher debt. More significant for our purposes, R_L is increasing in the variance of shocks: the return to lenders is concave in ε, so that an increase in variance needs to be compensated by higher R_L for lenders to break even. In other words, increased volatility causes the entire loan supply schedule to shift upward, as shown in Figure 1.

Optimal Debt Choice and Volatility

We assume that the sovereign borrower cares only about the expected utility of period-2 consumption and has a concave utility function U:[4]

$$E\left[U\left(C_2(\varepsilon, D)\right)\right]. \tag{5}$$

Consumption in period 2 is contingent on default. Let the distribution of shocks be given by the density function $\pi(\varepsilon)$. Denoting the consumption level in the event of default as C_{def} and in the event of "no default" as C_{nodef}, the borrower's problem is to choose D to maximize expected utility:

$$Max_D \int_{\varepsilon_m}^{e(R_L,D)} U\left(C_{def}\right)\pi(\varepsilon)\,d\varepsilon + \int_{e(R_L,D)}^{\varepsilon_m} U\left(C_{nodef}\right)\pi(\varepsilon)\,d\varepsilon, \tag{6}$$

subject to the condition that contractual interest rates satisfy the break-even condition.

[4]A more general model would allow for consumption in each period and let investment be distinct from the level of borrowing. Such a model, however, yields the same essential relationship as described in this model. In particular, it sheds no additional light on the relationship between volatility and default risk. The main difference lies in the fact that greater investment increases the collateral that lenders can capture in the event of default. A similar mechanism of achieving higher future consumption smoothing through greater seizeable collateral is discussed in Obstfeld and Rogoff (1996, pp. 422–25).

To describe the solution to this problem, we introduce additional notation. For any D, let $\phi(D)$ denote the ex ante probability of default. Define the utilities of consumption over default and nondefault states as follows:

$$MU_{def}(D) = \int_{\varepsilon_m}^{e(R_L,D)} U'(C_{def})\pi(\varepsilon)\,d\varepsilon$$

$$MU_{nodef}(D) = \int_{e(R_L,D)}^{\varepsilon_m} U'(C_{nodef})\pi(\varepsilon)\,d\varepsilon. \tag{7}$$

We now have the following proposition.

Proposition 1

At any interior solution D^* to the sovereign borrower's optimization problem, we have the following:

$$\phi(D^*) = \frac{1}{1+q}\left[\frac{MU_{def}(D^*)}{MU_{def}(D^*) + MU_{nodef}(D^*)}\right]. \tag{8}$$

The appendix provides a formal proof, but the intuition is straightforward. Debt is costly: in outcomes where default does not occur, the cost of carrying debt in this model is $D(R_L - R)$. At the same time, debt is valuable because it provides partial insurance against adverse shocks. The optimally chosen level of debt reconciles the marginal cost of debt with its benefits.

Significant for our purpose, the form of the solution provides insight into the relationship between income volatility and the likelihood of default. Consider a mean-preserving spread in the distribution of income shocks. Because of the concavity of the utility function, MU_{def} rises faster than MU_{nodef} so that the right-hand side must rise.[5] To restore equality, $\phi(D)$ must rise. In other words, higher volatility of income is associated with greater ex ante probability of default.

Note, in contrast, that the effect of volatility on the level of optimal debt is ambiguous and will depend on the borrower's degree of risk aversion. Greater volatility increases the risk premium for any given level of debt; this makes debt costlier, reducing the incentive to borrow. At the same time, greater volatility in consumption increases the incentive to borrow to smooth consumption. Given these opposing tendencies, the overall effect is ambiguous and, as simulations in Catão and Kapur (2004) show for plausible functional forms, can even be nonmonotonic.

It is useful to contrast the role of volatility in this model with that in Eaton and Gersovitz's (1981) classic model. In their infinite horizon model, default results in permanent exclusion from capital markets. To the extent that greater volatility increases the penalty of exclusion for borrowers, higher levels of volatility increase the incentive to repay and can support higher levels of debt. In our two-period model, we consider the impact of volatility not only on the desire to borrow for

[5]Strictly speaking, this argument requires that, at the optimum, $e(R_L(D^*),D^*)$—the threshold below which the borrower defaults—is increasing in the volatility of shocks. This is easy to check directly. See Catão and Kapur (2004) for details.

consumption smoothing, but also on the terms on which they borrow (that is, the spread). This allows for richer possibilities, including the theoretical possibility that greater volatility leads to higher risk of default. But, ultimately, the proof of the pudding is in the eating. As the econometric results presented next overwhelmingly indicate, volatility appears to be positively associated with higher default risk and lower borrowing on average.

II. Empirics

In light of the above model, testing the proposed explanation for debt intolerance requires empirically establishing two results. First, default risk should rise with income volatility, holding other factors constant. In general, default risk can be measured by the interest rate spread on sovereign debt, or by the observed frequency of sovereign "credit events," such as defaults and rescheduling of repayment. Given the lack of consistent long series on sovereign spreads, we choose, as the dependent variable in our regressions, the actual incidence of credit events over the period from 1970 to 2001.[6]

The second testable implication of the theory is that, although countries with greater volatility desire more debt than less volatile ones, they face more stringent borrowing conditions. Within the confines of the two-period setup, borrowing becomes more stringent because lending to more volatile countries is riskier; they face higher spreads, which dampens borrowing. This effect may be self-reinforcing in a richer multiperiod context. Suppose, for example, that greater volatility leads to greater frequency of default and raises the spreads. With higher spreads, the value of access to capital markets goes down, making default less costly. If the value of access decreases, the terms of access to capital markets may remain poor for highly volatile countries.

Table 1 reports some relevant descriptive statistics for a set of 26 developing countries that are mostly middle-income economies and that have been regular customers in private international capital markets.[7] Because a substantial share of these countries' external borrowing has been undertaken by the respective national governments whose debt-servicing problems have typically been the main trigger of sovereign defaults, the reported debt statistics exclude the domestic private sector external obligations. As in the remainder of the discussion, the focus is then on public sector external debt.[8]

[6]The main source of discontinuity in emerging market spread data is the transition from syndicated loans as the main borrowing instrument in the 1970s and 1980s to bond financing in the 1990s. Moreover, existing bond spread data for much of the 1990s suffers from a coverage bias, because the only countries represented are those that defaulted in the 1980s and converted their debt into Brady bonds. The unavailability of sufficiently long country spread series partly explains why other researchers also used actual information on credit events in probit or logit specifications in their empirical analyses of sovereign risk (for example, Feder and Just, 1977; Detragiache and Spilimbergo, 2001; and Reinhart, 2002).

[7]We exclude low-income countries because they rely much more on concessional and official multilateral debt, for which our model is less relevant. A similar cutoff has been adopted by RRS.

[8]Moreover, private sector debt statistics are not very reliable for emerging markets. This is because they rely on accurate balance of payments recording of private sector transactions or alternatively rely on firm-level survey data, rarely available for the entire 30-year period.

Table 1. Selected Macroeconomic and Debt Statistics, 1970–2001

	In-Sample Credit Events		Ypc_us	D/Y	D/X	$\sigma_{\Delta yr}$	$\sigma_{\Delta TOT}$
	Defaults	Reschedulings	(US$)	(%)	(%)	(%)	(%)
Argentina	2	0	7.7	23.5	252.1	5.1	13.6
Brazil	1	0	3.5	22.5	252.6	4.3	11.8
Chile	2	1	4.6	31.8	133.5	6.1	12.6
Colombia	0	0	1.9	23.5	152.5	2.4	14.7
Costa Rica	1	0	4.0	52.5	153.4	3.6	8.7
Ecuador	2	0	1.1	57.5	200.4	5.6	21.8
Mexico	1	0	5.8	27.7	173.6	3.7	18.9
Panama	1	0	3.4	62.3	92.9	5.4	11.2
Peru	1	2	2.0	37.5	247.5	5.5	11.8
Uruguay	1	0	6.0	34.0	169.2	4.1	11.5
Venezuela	1	0	5.0	36.0	132.8	4.4	31.8
India	0	0	0.5	17.6	247.1	3.0	6.6
Indonesia	0	1	0.7	35.7	143.4	4.1	15.7
Korea	0	0	9.8	6.6	23.1	3.8	6.6
Malaysia	0	0	3.9	24.2	39.1	6.6	7.6
Pakistan	1	0	0.4	52.7	427.5	2.6	13.5
Philippines	1	0	1.0	33.1	120.9	3.6	8.3
Thailand	0	0	2.0	14.6	49.2	4.4	9.5
Singapore	0	0	23.0	2.1	0.4	4.0	4.4
Egypt	1	0	1.5	43.9	215.1	4.1	12.8
Bulgaria	1	0	1.5	52.8	133.1	5.5	18.3
Hungary	0	0	4.8	44.6	117.8	4.5	11.6
Poland	1	0	4.1	36.5	162.6	6.3	3.7
Russia	2	0	1.8	48.0	132.5	6.7	13.9
South Africa	1	0	2.9	2.0	7.5	2.3	6.5
Turkey	1	0	3.0	22.4	231.3	4.4	6.2
Mean	0.85	0.15	4.1	32.5	154.3	4.5	12.1

Sources: Credit event data from Lindert and Morton (1989), Beim and Calomiris (2000), and IMF staff. Other data from IMF International Financial Statistics, World Bank country database, and authors' own calculations.

Notes: Ypc_us = Per capita GDP in US$ thousands in year 2000.
D/Y = Debt-to-GDP ratio, 1970–2001 average.
D/X = Debt-to-export ratio, 1970–2001 average.
$\sigma_{\Delta yr}$ = Standard deviation of real GDP growth, 1970–2001.
$\sigma_{\Delta TOT}$ = Standard deviation of terms of trade growth, 1970–2001.

The first noteworthy feature of the data is the recurrence of credit events (defined as defaults or rescheduling) in some countries and the complete absence of such events in others. As noted earlier, studies that consider longer periods confirm the impression of serial correlation in default (Lindert and Morton, 1989; and RRS). Table 1 also suggests that this pattern is not necessarily correlated with per capita income (measured in thousands of 2000 U.S. dollars, *Ypc_us*). Some serial defaulters (for example, Argentina) are several times richer than countries that never defaulted (for example, India).

The second interesting feature of the data is that an average emerging market debt-to-GDP ratio (*D/Y*) of 33 percent is not only unremarkable, but also much lower than those commonly observed for most advanced countries. Within our sample, the majority of serial defaulters have low to moderate debt ratios. Year-by-year inspection of the data (not shown here because of space constraints) indicates that for most of the defaulters the debt-to-GDP ratios on the eve of their defaults were less than 40 percent. Table 1 also indicates that once debt is scaled by exports (*D/X*), rather than by GDP, the correlation between default events and debt burdens tightens considerably, although some important outliers remain. As shown below, regression results corroborate this prima facie association, lending support to the widespread use of the debt-to-export ratio as a risk indicator in countries' credit rating assessments.

But arguably the most striking association highlighted in Table 1 is the one between those credit events and macroeconomic volatility. All of the serial defaulters in our sample (Argentina, Chile, Ecuador, Peru, and Russia) had unconditional output volatility ($\sigma_{\Delta y_r}$) above the sample average. Because the latter is, in turn, about twice as high as the average output volatility of OECD economies during the same period, it follows that serial defaulters are indeed highly volatile economies. In contrast, nondefaulting countries, such as Colombia, India, Korea, Thailand, Singapore, and Hungary, all have below average output volatility.[9] Of course, such association does not imply causality, because default events may themselves be a source of output volatility. Yet, using external terms of trade as an indicator of both the exogenously determined component and the purchasing power of national output,[10] it also appears that countries with more volatile TOT appear to default more often. This can be seen from the fact that nearly all Latin American emerging markets (in the first 12 rows of the table) had both eventful credit histories and relatively high TOT volatility, whereas all default-free Asian economies (positioned in the middle of the table) had much lower TOT volatility. TOT volatility has also been relatively high among all Eastern European defaulters, with the exception of Poland.

To understand these relationships more rigorously, and to test their robustness to the inclusion of other variables featured in previous studies, we estimate a discrete choice model of the default probability. As suggested by the theoretical discussion in Section I, the default probability can be generally written as the following function:

$$\phi = f\left(D, R, Y, \eta, q, \sigma_\varepsilon\right), \tag{9}$$

[9]South Africa would also fit this story if not for the external political sanctions that triggered the 1985 default. Malaysia is the biggest outlier in the default-volatility association, but its outlier behavior is crucially dependent on the inclusion of the Asian crisis in the sample. In fact, when the Asian crisis years of 1997–99 are taken out of the sample, the association between output volatility and default frequency is further reinforced for Asian economies.

[10]Use of external TOT as a yardstick of the exogenous component of domestic income volatility is consistent with evidence from the developing country business cycle literature, which estimates that TOT accounts for nearly one-half of overall income volatility in developing countries (Mendoza, 1995). Kose and Riezman (2001) report similar estimates disaggregating between export and import prices.

where $\partial\phi / \partial D > 0$, $\partial\phi / \partial R > 0$, $\partial\phi / \partial\bar{Y} < 0$, $\partial\phi / \partial\eta < 0$, and $\partial\phi / \partial\sigma_\varepsilon > 0$, while the sign of $\partial\phi/\partial q$ is ambiguous. The sign is ambiguous because of the existence of a range of sufficiently high values of q, which depress debt to an extent that default risk is lowered (see Catão and Kapur, 2004, for a discussion and numerical illustrations of this point).

In deciding whether to model the discrete choice between the nonevent "0" (nondefault in our case) and the realization of the event "1" (default), empirical researchers are divided between the use of a logit or a probit specification. In most cases, the differences are not significant (see Greene, 2000, p. 815, for a discussion and references). One approach is to choose logit or probit on the basis of standard maximum likelihood criteria given the same set of left-hand-side variables. On this basis, we chose a logit specification because it fits the data slightly better.

Table 2 reports the results for a variety of alternative specifications over the panel of countries listed in Table 1. To mitigate potential endogeneity biases, all ratios and level variables enter the regressions lagged one period, and the respective z-statistics are corrected for country-specific heteroscedasticity using the standard White procedure. In addition, to mitigate the endogeneity biases arising from the fact that debt crises have their own intrinsic dynamics that can exacerbate a country's historic volatility, all observations between the time of default and the end of a debt crisis (as measured by the country's reentry into capital markets as defined in Beim and Calomiris, 2000, pp. 32–6) are dropped from the regression.[11] The list of explanatory variables includes the following: We take the U.S. 10-year bond rate, deflated by the current U.S. CPI, as a proxy for the risk-free (real) interest rate, and denote it as r^*. We include export to GDP as an explanatory variable in some regressions; this may be viewed as a proxy for the capture rate η, which the existing literature typically associates with trade disruption (Bulow and Rogoff, 1989; and Rose, 2002).[12] The volatility variable σ_{ygap} refers to the standard deviation of the ratio between actual and trend or "potential" real GDP (the so-called "output gap"), computed over the previous 10 years at each point in time and rolled forward year on year.[13]

Column (1) of Table 2 reports the results of a specification that includes the risk-free interest rate r^*, the volatility of output, and the ratios of debt to potential output (D/Yp) and export to GDP (X/Y). Estimated coefficients on the risk-free rate r^* and the output volatility variable σ_{ygap} take on the expected sign and are highly significant statistically. The coefficients on D/Yp and X/Y have the correct sign, but these are estimated with much less precision. Because they have a similar order of magnitude and opposite signs, however, this suggests that they can be combined

[11]This procedure is similar to that adopted by Frankel and Rose (1996) in their well-known study on the determinants of currency crises.

[12]We also experimented with the ratio of exports plus imports to GDP, but the export-to-GDP ratio was the openness indicator closest to statistical significance.

[13]Potential real GDP is derived from an HP-filter with the smoothing parameter λ set to 7 as suggested in Pesaran and Pesaran (1997, p. 47) for annual data. The use of a 10-year moving window allows for slowly evolving changes in the underlying distribution of shocks over time for any given country. Such rolling volatility measures have also been used in studies on the impact of TOT instability on economic growth (for example, Mendoza, 1997; and Blattman, Hwang, and Williamson, 2006).

Table 2. Logit Estimates of Default Probabilities with Output Gap Volatility
(Marginal effects with robust z-statistics in parentheses)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
r*	0.43	0.62	0.61	0.75	0.57	0.39	0.17	0.19
	(3.72)**	(3.90)**	(4.20)**	(4.39)**	(3.69)**	(4.37)**	(4.06)**	(3.98)**
$\sigma_{10}\_y_{gap}$	0.37	0.56	0.49		0.58	0.35	0.13	0.14
	(3.80)**	(4.13)**	(2.91)**		(4.38)**	(4.29)**	(2.87)**	(2.73)**
D/X		0.003	0.003	0.004	0.003	0.03	0.0004	
		(2.30)*	(2.25)*	(2.15)*	(2.30)*	(2.50)*	(0.74)	
D/Yp	0.02							
	(1.58)							
X/Y	–0.03							
	(–1.69)							
Def_freq			0.02	0.02				
			(1.07)	(1.91)				
REER_gap						0.08	0.01	0.03
						(3.98)**	(2.28)*	(2.16)*
Fxnet/M					–0.01			
					(–1.76)			
DS_X							0.01	0.01
							(6.47)**	(6.92)**
pseudo-R^2	0.26	0.23	0.24	0.19	0.24	0.31	0.49	0.49
Wald χ^2	38.4	27.3	37.7	32.4	29.3	56.2	78.3	73.1
No. of observations	588	588	588	588	588	588	588	588

Sources: Credit event data from Lindert and Morton (1989), Beim and Calomiris (2000), and IMF staff. Other data from IMF *International Financial Statistics,* World Bank country database, and authors' own calculations.

Notes: * significant at 5 percent; ** significant at 1 percent.

in a single indicator—the ratio of debt to exports. Column (2) reports the results with the debt-to-export variable, which is clearly statistically significant at 5 percent. As before, r* and σ_{ygap} remain important determinants of default risk, and the regression passes the Wald test for joint significance with flying colors. Moreover, while a pseudo-R^2 of 0.23 may appear low, it is in fact marginally higher than in other empirical studies applying logit/probit models to sovereign risk analysis (see Detragiache and Spilimbergo, 2001; and Reinhart, 2002).

Columns (3) and (4) report the results of experimenting with the credit history variable used in RRS—the proportion of years the country was in default since 1820. Column (3) indicates that this variable is not statistically significant at any conventional level. Interestingly, however, once the volatility variable σ_{ygap} is dropped from the regressions as shown in column (4), the credit history variable becomes significant at the 5 percent borderline. This suggests that the credit history indicator is a catchall variable proxying the more fundamental effects of underlying macroeconomic volatility on sovereign risk. In other words, this result suggests that countries that defaulted more often in the past are more likely to default more often in the future to the extent that the underlying sources of output volatility in these economies continue unabated.

Also important, our results indicate that the significance of the volatility variable is robust to the inclusion of a wide array of explanatory variables featured in the sovereign debt literature. The ratio of net foreign exchange reserves to imports (*Fxnet/M*) may capture liquidity factors and, as such, is widely used in empirical analyses of country risk (Edwards, 1984; Eichengreen and Portes, 1986; Cantor and Packer, 1996; and Hu, Kiesel, and Perraudin, 2002). As shown in column (5), however, this variable falls short of statistical significance at 5 percent. Its failure to improve the model's fit is clearly corroborated by the virtually unchanged pseudo-R^2 of the regression that includes it relative to the one that does not (see column (3)). Conversely, an indicator of real exchange rate misalignment (the real effective exchange rate gap), which also features prominently in empirical studies of currency and debt crises (see, for example, Frankel and Rose, 1996), does much better.[14] This is not surprising because this variable captures debt-denomination effects on sovereign risk that, while abstracted from the simple model of Section I, are deemed to be important (see Eichengreen and Hausmann, 1999).

The second variable of significance is the ratio of debt service to exports, with the inclusion of this variable substantially improving the fit of the regressions as shown in the last two columns of Table 2. This, again, is not surprising because, in a world in which debt maturity varies widely across countries and over time, debt service is arguably a more effective proxy for the next period's repayment costs featured in the theoretical model. And partly because of its obvious collinearity between the debt-service-to-export ratio (*DS_X*) and the *D/X* variable, the *DS_X* variable clearly dwarfs the former. Column (8) thus reports estimates for which the *D/X* variable is dropped and the *DS/X* variable enters as the only debt burden

[14]As others have done, we measure misalignment by deviations of the IMF's real effective exchange rate index from a univariate trend, which, in our case, is again derived from an HP-filter with the smoothing parameter λ set to 7.

Table 3. Logit Estimates of Default Probabilities with Alternative Volatility Measures

(Marginal effects with robust z-statistics in parentheses)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
r*	0.46	0.49	0.46	0.45	0.20	0.23	0.22	0.19
	(4.51)**	(4.79)**	(4.73)**	(4.53)**	(3.74)**	(3.72)**	(3.97)**	(3.82)**
REER_gap	0.10	0.10	0.09	0.10	0.03	0.03	0.04	0.03
	(4.17)**	(4.10)**	(4.85)**	(4.25)**	(2.07)*	(1.97)*	(2.47)*	(2.13)*
D/X	0.00	0.00	0.00	0.00				
	(1.86)	(1.73)	(1.77)	(1.86)				
DS_X					0.02	0.02	0.02	0.02
					(6.31)**	(6.38)**	(6.48)**	(6.38)**
σ_{10}_***tot***	0.03			0.03	0.02			0.01
	(4.01)**			(3.73)**	(4.16)**			(3.84)**
σ_5_***tot***		0.05				0.02		
		(3.62)**				(3.36)**		
$\sigma_{10}\_\varepsilon_y$			0.09				0.04	
			(2.28)*				(2.44)*	
$\sigma_{10}\_\varepsilon_{yxtot}$								
				0.06				0.02
				(1.27)				(1.79)
pseudo-R^2	0.30	0.30	0.28	0.30	0.49	0.48	0.47	0.49
Wald χ^2	40.99	40.33	35.52	41.61	58.96	57.63	69.14	63.73
No. of observations	588	588	588	588	588	588	588	588

Sources: Credit event data from Lindert and Morton (1989), Beim and Calomiris (2000), and IMF staff. Other data from IMF *International Financial Statistics*, World Bank country database, and authors' own calculations.

Note: * significant at 5 percent; ** significant at 1 percent.

indicator. Finally, we have tested the best-fit models in columns (7) and (8) with the addition of several variables that appear in other studies, including per capita income, real GDP growth, and regional dummies. None of these variables proved to be statistically significant at 5 or 10 percent.

We further test the robustness of the hypothesis that domestic volatility raises default risk by checking whether this holds for alternative volatility measures. In particular, one potential criticism of the results of Table 2 is that output gap volatility is not strictly endogenous to the extent that it may be a byproduct of default risk perceptions and possibly a lingering outcome of the country's previous repayment history. Another potential concern is that the output volatility measure of Table 2 does not distinguish between expected and unexpected shocks to GDP. Although this distinction does not play a role in the theoretical setup of Section I, it may be important in practice and it needs to be considered.

Estimation results in Table 3 address both types of concerns. As before, all explanatory variables are lagged one period except for the TOT indicator (which, as discussed earlier, can be taken as exogenous), and the respective z-statistics are corrected for country-specific heteroscedasticity. Using TOT volatility as a gauge for domestic output volatility, the estimates show that our previous results hold: not only is TOT volatility statistically significant, but also the overall fit of the regressions does not change much. This is so irrespective of whether one uses the debt stock-to-export ratio (D/X) as the indicator of debt burden (and hence of the gains of defaulting) or, alternatively, the debt service-to-export ratio (DS/X). This result also holds whether one uses 5-year or 10-year rolling standard deviations of TOT. The only noticeable difference with regard to results in Table 2 is that the D/X variable is only significant at 10 percent.

Table 3 also shows (columns (3) and (7)) estimates with 10-year rolling standard deviations of the residuals of a country-specific real GDP growth forecasting equation ($\sigma_{10\_\varepsilon y}$) aimed at capturing unanticipated shocks to output. Following Ramey and Ramey (1995), such a growth forecasting equation includes two lags of real GDP levels, a linear time trend and a segmented trend broken in 1974.[15] This shock volatility indicator has the expected positive sign and is also significant at 5 percent, although the classic generated regressor bias problem tends to detract from its statistical significance. Finally, we consider a small variant of the former measure by including two lags of TOT in the growth forecasting equation. This makes the residual ($\sigma_{10\_\varepsilon_{xtot}}$) less correlated with the TOT volatility indicator and more likely to capture unexpected shocks associated with other variables, such as fiscal and monetary policies. The results reported in columns (4) and (8) indicate that this measure is not significant at 5 percent, which may be due to the generator bias problem noted above. In both cases, TOT volatility remains highly statistically significant.

Having shown that default probability is positively and significantly related to output and TOT volatility controlling for other factors, we now turn to the evidence pertaining to the impact of volatility on indebtedness levels. Section I established

[15]As discussed in their paper, this measure is consistent with the hypothesis of a unit root as well as with the alternative of a trend-stationary or a segmented-trend stationary real GDP.

Table 4. Determinants of Sovereign Debt: Regime Switching Model Estimates
(Dependent variable: external debt to GDP, z-statistics in parentheses)

	(1)		(2)		(3)		(4)		(5)	
	d^*	d_{max}	d^*	d_{max}	d^*	d_{max}	d^*	d_{max}	d^*	d_{max}
σ10_*Yg*	7.23	−12.01	30.65	−11.18	57.49	−11.25	82.43	−10.80	—	—
	(0.66)	(−8.85)	(2.49)	(−8.60)	(4.17)	(−8.63)	(3.91)	(−8.54)	—	—
(X+M)/GDP	−1.22	0.84	−1.22	0.75	−0.41	0.74	−0.78	0.74	−0.71	0.84
	(−6.20)	(26.82)	(−6.41)	(24.93)	(−2.01)	(23.44)	(−3.23)	(24.19)	(−3.45)	(28.51)
Zo	—	0.60	—	0.52	—	0.52	—	0.5	—	0.49
	—	(7.96)	—	(7.68)	—	(7.43)	—	(7.50)	—	(6.15)
Growth			−17.24	−3.21	−17.19	−3.21	−12.59	−2.92	−8.72	−3.31
			(−6.48)	(−7.24)	(−6.89)	(−7.24)	(−4.91)	(−6.71)	(−3.46)	(−6.60)
Ypc_us					−1.07	—	−0.87	—	−0.58	—
					(−7.25)	—	(−6.50)	—	(−5.37)	—
Political stability							−2.63	—	−1.28	—
							(−3.18)	—	(−2.58)	—
σ10_*TOT*									5.08	−0.81
									(3.49)	(−5.54)
Max. likelihood	−871.3		−818.3		−792.6		−781.4		−806.3	
No. of observations	710		710		710		710		710	

Sources: Credit event data from Lindert and Morton (1989), Beim and Calomiris (2000), and IMF staff. Other data from IMF *International Financial Statistics*, World Bank country database, and authors' own calculations.

that the net effect of volatility on indebtedness is ambiguous on purely theoretical grounds but that sensible model calibrations suggest the direction of the effect to be mostly negative. The remainder of this section tests this hypothesis.

As discussed in Eaton and Gersovitz (1981), econometric estimation of the effect of income volatility on debt levels is not trivial. In part, this is because of the potential presence of a credit ceiling under which standard ordinary least squares (OLS) estimates tend be inconsistent due to the truncated nature of the distribution. In addition, such a credit ceiling shifts according to the various parameters of the model. One way to model this problem—which has been advanced in Maddala and Nelson (1974) and used by Eaton and Gersovitz (1981) as well as in several other distinct macro applications (for example, Portes and Winter, 1980)—is to assume that debt at any given point in time is determined within either of the two regimes: one in which demand factors predominate and one in which the supply constraint becomes binding (see Maddala, 1986, for a comprehensive discussion and further references on the underlying econometric issues).

Since a switch between these two regimes in practice is likely, and given that d_{max} is unobserved, the proposed estimation technique that allows for this possibility amounts to estimating the following system:

$$\begin{aligned} d^*_{i_t} &= g\left(\sigma_{y_{it}}, \eta_{it}, q_{it}\right) \\ d_{\max i_t} &= h\left(\sigma_{y_{it}}, \eta_{it}, q_{it}, z_{0_{it}}\right), \\ d_{it} &= \min\left(d_{\max i_t}, d^*_{it}\right) \end{aligned} \tag{10}$$

where d^*_t is a point in the demand schedule before d approaches the maximum debt threshold regime. The main estimation challenges in this case are that (1) d^*_{it} and $d_{\max i_t}$ are unobserved, and (2) there must be a meaningful way to distinguish the supply constrained regime from its alternative, the "unconstrained" market equilibrium regime. Conditional upon the latter requirement, a maximum likelihood method for this type of model has been advanced by Maddala and Nelson (1974). In what follows, we thus estimate equation (10) by full maximum likelihood using OLS estimates as the starting values for the nonlinear optimization. Regarding identification, we discriminate between the two regimes by introducing in the d_{max} equation a dummy variable $z_{0_{it}}$, which equals one for periods in which the country is in default (when indebtedness is known to be supply constrained) and zero otherwise.

The results are reported in Table 4. In light of the theoretical model of Section I, we start with a baseline specification that expresses the debt-to-GDP ratio as function of underlying income volatility (as before, proxied by the 10-year rolling standard deviation of the output gap) and trade openness.[16] Clearly, such a highly parsimonious model should not be expected to fully capture the complexity of sovereign indebtedness decisions. Yet, as it turns out, its predictions regarding the

[16]As others have done (for example, Eaton and Gersovitz, 1981), we express those ratio variables in natural logs. Using the export-to-GDP ratio instead of the export-plus-imports-to-GDP ratio does not alter the thrust of the results. In the absence of other information, we assume the deadweight loss parameter q to be constant throughout the estimation.

effects of volatility on borrowing are not overturned by richer specifications. Consistent with our theoretical model, higher income volatility shifts downward the maximum debt threshold (d_{max}), with column (1) estimates indicating that a 1 percentage point change in the underlying real GDP volatility leads to a 12 percent decline in the d_{max}, all else constant (the semi-elasticity estimate is basically unchanged across specifications). Likewise, consistent with the model, greater trade openness (a proxy for default costs, as already discussed) tends to increase d_{max}, while the coefficient on the default period dummy *Zo* also takes on the expected positive sign. Regarding the unconstrained regime d^*, the baseline specification estimates are no less sensible. Consistent with the consumption smoothing motive for borrowing, volatility affects debt positively, and although the respective coefficient is imprecisely estimated (as witnessed by the z-statistic of 0.66), we shall see below that it will become highly statistically significant in more comprehensive specifications. The openness indicator takes on a negative sign and is highly significant, supporting the view that higher default costs in a volatile environment with nontrivial default probabilities tend to discourage borrowing.

This baseline specification is then augmented in column (2) by the (one-period-lagged) GDP growth rate. The effects of economic growth on optimal debt are important for the reasons, among others, laid out in Eaton and Gersovitz (1981): on the one hand, a higher growth rate of domestic income tends to encourage borrowing for Fisherian reasons (that is, some of the future income is desired now); on the other hand, higher growth may reduce a lender's capture power (for instance, by lowering the cost of a future credit embargo). Our estimates indicate that although the effect of growth in the supply constrained regime is consistent with the Eaton-Gersovitz mechanism, its effect on optimal debt in the unconstrained regime is opposite to that postulated by the Eaton-Gersovitz demand for borrowing—that is, higher GDP growth tends to discourage rather than encourage borrowing. This result, however, is not implausible and can be easily rationalized.[17] More relevant to the core of our hypothesis is the fact that the signs and statistical significance of the estimated coefficients on both the unconstrained and constrained regimes are consistent with this paper's proposed explanation for debt intolerance. The main difference with the baseline specification is the coefficient on the volatility variable in the unconstrained regime, which now appears to be highly significant statistically. In addition, this highly positive coefficient suggests that the volatility-induced effect on debt demand is strong before the supply constraint kicks in with a vengeance. On average, inspection of the fitted values for this regression indicates that 30 percent of the fitted values falls on the d^* regime, with 70 percent falling on the constrained

[17]It is possible, for instance, that this opposite sign reflects the shortcomings of proxying future growth potential on the basis of lagged growth (although Eaton and Gersovitz, 1981, use the same lagged indicator). Some multicollinearity is also possible between volatility and the growth rate indicator for the reasons highlighted in Ramey and Ramey (1995)—that is, the existence of a statistically significant association between volatility and growth. Indeed, the sharp change in the coefficient of the volatility variable after growth is included in the unconstrained regime suggests that multicollinearity plays a role. Finally, it may also be conjectured that higher growth tends to improve the sovereign budget, hence mitigating borrowing needs.

regime, thereby indicating that the supply constraint for these countries is binding most of the time. This finding is clearly consistent with the view of debt intolerance being a systematic rather than episodic phenomenon.

The remainder of Table 4 reiterates the robustness of the above results. Adding countries' U.S. dollar per capita income as an explanatory variable (see column (3)) and using TOT instead of real GDP variance has an impact only on the magnitude of the effect rather than on its direction or statistical significance. Finally, estimates reported in column (4) add a variable that the political economy literature has deemed as an important determinant of fiscal performance and hence of debt accumulation—namely, a country's degree of political stability (Alesina and Drazen, 1991; and Cukierman, Edwards, and Tabellini, 1992).[18] In tandem with the findings of this literature, which postulates that politically less stable countries tend to run more persistent fiscal deficits and hence demand more debt, we find that greater political *stability* tends to lower debt. At the same time, the estimates also show that the inclusion of this additional variable does not change the thrust of the previous results—with volatility and openness remaining significant determinants of sovereign indebtedness. Finally, as in previous specifications, the model's fitted values classify that the majority of observations (77 percent) belong to the supply constrained regime, thus clearly indicating that volatility depresses rather than encourages borrowing most of the time.

III. Conclusions

The fact that most sovereign defaults have taken place in countries with low to moderate debt-to-income ratios is puzzling. This puzzle is all the more remarkable when one notes that many other sovereigns have far-higher debt ratios and continue to borrow at much lower spreads. While reputation and cross-country differences in credit histories have been invoked as reasons, such explanations raise a number of thorny questions as discussed above.

This paper argues that cross-country differences in underlying macroeconomic volatility are at least part of the answer and are a key missing link that reconciles the standard theory of sovereign borrowing with the empirical evidence on the debt-intolerance phenomenon. The root of our argument is not something new. It is well documented that many emerging markets are more volatile than both their advanced counterparts and other developing country peers, and that this volatility comes from diverse sources—from TOT volatility associated with narrow commodity specialization to institutions that are conducive to destabilizing economic policies (see Gavin and others, 1996; Talvi and Végh, 2002; Acemoglu and others, 2003; and Blattman, Hwang, and Williamson, 2006). Given the case made by Acemoglu and others (2003), that exogenous institutional factors seem to be at the root of much of this underlying volatility, this paper has focused on the effects—rather than the causes—of such volatility on sovereign default risk and optimal indebtedness. The evidence overwhelmingly suggests that, historically,

[18]The political stability variable is the widely used Freedom House index, ranging from 0 (maximum political instability) to 1 (fully stable democracy).

more volatile countries tend to carry a higher default risk and face a lower credit ceiling, even when one controls for a host of other variables. In addition, our econometric estimates indicate that supply constraints are binding most of the time (just over two-thirds of the sample observations), thereby suggesting that market intolerance to higher indebtedness among this group of countries is a systematic rather than an episodic phenomenon. This finding corroborates that of RRS, using a different methodology and slightly different country coverage.

This paper's emphasis on the role of volatility in sovereign risk does not rule out other factors previously identified in the literature. One such factor is currency-denomination mismatches in borrowers' balance sheets and the associated role of exchange rate misalignment in debt crises (Eichengreen and Hausmann, 1999 and 2005). Although isolating the role of income volatility on sovereign borrowing in a tractable way has led us to abstract from the balance sheet channel in our theoretical analysis, such effects have been controlled for in our regressions. As seen above, the respective results corroborate the importance of this variable, consistent with what previous researchers have found. Similarly, by focusing on the effects of underlying or structural macroeconomic volatility on debt servicing, we are not necessarily rejecting an autonomous role for sovereign reputation. Our results do suggest that macroeconomic volatility is a fundamental factor that, among other things, can easily manifest in unsound credit histories and hence shape reputation.

Some implications follow directly from these results. First, contrary to the classic Eaton and Gersovitz (1981) mechanism—which suggests that volatility might lower the incentive to default—we find that volatility does not raise countries' credit ceilings; in fact, the opposite occurs. Although the literature on sovereign debt observes that defaults tend to occur during extreme economic downturns, thus implying that countries that face such events more frequently carry a higher risk, a significant contribution of this paper's empirical analysis has been to model and test this proposition conditional on a variety of other factors. Our findings also qualify a key inference drawn by RRS. In their view, a sovereign's reputation (built over decades or centuries) is a crucial determinant of debt intolerance. Thus, overcoming the latter would require many of today's emerging economies to dramatically lower their debt ratios to the point at which their default risk is sufficiently low (their estimated threshold being as low as 15 percent in some cases), so that debt becomes "sustainable." This would then make possible a gradual buildup of reputation, which would eventually enhance the countries' borrowing capacity. Aside from the point that their own empirical analysis suggests that gradual deleveraging is hard to accomplish and that reputation building is a painfully slow process, our model cautions that such debt-reduction strategies may be suboptimal if they preclude feasible consumption smoothing and do not ultimately address the sources of domestic income volatility.

This takes us to a paradoxical aspect of the debt-intolerance phenomenon highlighted by this paper's results. On the one hand, more volatile countries have greater need for international borrowing for consumption smoothing purposes; on the other hand, these are precisely the countries that will face the most stringent constraints on their borrowing capacity because of the default risk that volatility itself engenders. Thus, by reducing volatility, a country can improve its maximum indebtedness threshold but at the same time reduce its desire for debt. Which effect will prevail is an empirical issue; in practice, this will partly depend on other motives driving international borrowing besides consumption smoothing. Provided that these other motives are sufficiently weighty, reducing macroeconomic volatility should translate to more, rather than less, emerging market borrowing. In addition, because the sovereign spread is a well-known benchmark when setting interest rates for the domestic private sector, by reducing the former, lower macroeconomic volatility should be instrumental in helping reduce the latter and thus positively affect economic growth. Thus, this channel linking volatility and sovereign spreads is one other plausible explanation for the inverse relationship between output and TOT volatility and economic growth extensively documented elsewhere (Ramey and Ramey, 1995; Mendoza, 1997; Agénor and Aizenman, 1998; and Blattman, Hwang, and Williamson, 2006).

Finally, our theoretical and empirical analyses both suggest an alternative channel through which countries' borrowing capacity can be increased without lowering volatility and depressing sovereign loan demand. This channel is the lenders' "capture technology," as represented by parameters η and q in our model. While the effectiveness of this mechanism is constrained by the limits imposed by national sovereignty, it is clear that if an economy is open enough that default entails potentially significant trade and other output losses (a higher η), and debt recovery plus spillover default losses are not overly high (that is, q is sufficiently low), then lenders will be more assured that default is less likely. This will shift downward the loan supply schedule, thereby raising the sovereign's credit ceiling. The empirical significance of this mechanism is overwhelmingly supported by our econometric results, which indicate that higher openness reduces default probability and raises the maximum debt threshold. To the extent that greater borrowing capacity tends to enhance an economy's growth potential, this also provides a rationale for the empirical results reported in Kose, Prasad, and Terrones (2006) that greater trade openness tends to mitigate the well-documented trade-off between volatility and economic growth. Thus, provided that it does not generate some volatility of its own, greater trade openness naturally emerges as instrumental in mitigating the impact of higher domestic volatility on default risk.

APPENDIX

Proof of Proposition 1

Let $R_L(D)$ be a functional relationship that defines the break-even constraint. Given $R_L(D)$, the borrower's optimization problem is as follows:

$$Max_D = \int_{-\varepsilon_m}^{e(R_L(D),D)} U\left(C_{def}\right)\pi(\varepsilon)\,d\varepsilon + \int_{e(R_L(D),D)}^{+\varepsilon_m} U\left(C_{nodef}\right)\pi(\varepsilon)\,d\varepsilon,$$

where
$$C_{def} = (1-\eta)(\bar{Y} + \varepsilon + RD)$$
$$C_{nodef} = \bar{Y} + \varepsilon + \left[R - R_L^*(D)\right]D.$$

The first-order condition for an interior maximum (provided it exists) is $V_D = 0$, where

$$V_D = \int_{-\varepsilon_m}^{e(D,R_L^*(D))} U'[(\bar{Y}+\varepsilon+RD)(1-\eta)](1-\eta)R\,\pi(\varepsilon)\,d\varepsilon$$

$$+\int_{e(D,R_L^*(D))}^{\varepsilon_m} U'\left[\bar{Y}+\varepsilon+\left(R-R_L^*(D)\right)D\right]\left(R-R_L^*(D)-\frac{\partial R_L^*}{\partial D}D\right)\pi(\varepsilon)\,d\varepsilon.$$

Noting that the break-even constraint $\int_{-\varepsilon_m}^{\varepsilon_m} P^*(\varepsilon, R_L, D)\pi(\varepsilon)\,d\varepsilon = RD$ implies

$$\frac{\partial R_L}{\partial D} = -\frac{1}{D}\left[R_L - R\left(1+(1-\eta)\frac{(1-q)\phi}{1-\phi(1+q)}\right)\right],$$

we use this relation in the first-order condition to derive:

$$V_D = \int_{-\varepsilon_m}^{e(D)} U'\left[C_{def}(D,\varepsilon)\right]\pi(\varepsilon)\,d\varepsilon - \frac{(1+q)\phi}{1-\phi(1+q)}\int_{e(D)}^{\varepsilon_m} U'\left[C_{nodef}(D,\varepsilon)\right]\pi(\varepsilon)\,d\varepsilon = 0.$$

Rearranging the above equation yields:

$$\phi = \frac{1}{1+q}\frac{\int_{-\varepsilon_m}^{e} U'\left(C_{def}\right)\pi(\varepsilon)\,d\varepsilon}{\int_{-\varepsilon_m}^{e} U'\left(C_{def}\right)\pi(\varepsilon)\,d\varepsilon + \int_{e}^{\varepsilon_m} U'\left(C_{nodef}\right)\pi(\varepsilon)\,d\varepsilon}.$$

REFERENCES

Acemoglu, D., S. Johnson, J. Robinson, and Y. Thaicharoen, 2003, "Institutional Causes, Macroeconomic Symptoms: Volatility, Crises and Growth," *Journal of Monetary Economics,* Vol. 50 (January), pp. 49–123.

Agénor, Pierre-Richard, and Joshua Aizenman, 1998, "Contagion and Volatility with Imperfect Credit Markets," *Staff Papers,* International Monetary Fund, Vol. 45 (June), pp. 207–35.

Alesina, Alberto, and Allan Drazen, 1991, "Why Are Stabilizations Delayed?" *American Economic Review,* Vol. 81 (December), pp. 1170–88.

Alfaro, Laura, and Fabio Kanczuk, 2005, "Sovereign Debt as a Contingent Claim: A Quantitative Approach," *Journal of International Economics,* Vol. 65 (March), pp. 297–314.

Beim, David O., and Charles W. Calomiris, 2000, *Emerging Financial Markets* (New York: McGraw-Hill/Irwin).

Blattman, Christopher, Jason Hwang, and Jeffrey Williamson, 2006, "Winners and Losers in the Commodity Lottery: The Impact of Terms of Trade Growth and Volatility in the Periphery 1870–1939," *Journal of Development Economics* (forthcoming).

Bulow, Jeremy, and Kenneth Rogoff, 1989, "Sovereign Debt: Is to Forgive to Forget?" *American Economic Review,* Vol. 79 (March), pp. 43–50.

Caballero, Ricardo, 2000, "Macroeconomic Volatility in Latin America: A Conceptual Framework and Three Case Studies," *Economia,* Vol. 1 (Fall), pp. 31–108.

Cantor, R., and F. Packer, 1996, "Determinants and Impact of Sovereign Credit Ratings," Federal Reserve Board of New York, *Economic Policy Review,* Vol. 2 (October), pp. 37–53.

Catão, Luis, and S. Kapur, 2004, "Deadweight Losses in Sovereign Debt" (unpublished).

Cohen, Daniel, 1992, "Postmortem on the Debt Crisis," in *NBER Macroeconomics Annual 1992,* (Cambridge, Massachusetts: MIT Press).

Cukierman, Alex, Sebastian Edwards, and Guido Tabellini, 1992, "Seignorage and Political Instability," *American Economic Review,* Vol. 82, pp. 537–55.

Detragiache, Enrica, and Antonio Spilimbergo, 2001, "Crises and Liquidity: Evidence and Interpretation," IMF Working Paper 01/02 (Washington: International Monetary Fund).

Díaz-Alejandro, Carlos F., 1984, "Latin American Debt: I Don't Think We Are in Kansas Anymore," *Brookings Papers on Economic Activity: 2,* Brookings Institution, pp. 335–403.

Eaton, Jonathan, and Mark Gersovitz, 1981, "Debt with Potential Repudiation: Theoretical and Empirical Analysis," *Review of Economic Studies,* Vol. 48 (April), pp. 289–309.

Edwards, Sebastian, 1984, "LDC's Foreign Borrowing and Default Risk: An Empirical Investigation, 1976–80," *American Economic Review,* Vol. 74 (September), pp. 726–34.

Eichengreen, Barry, and Ricardo Hausmann, 1999, "Exchange Rates and Financial Fragility," NBER Working Paper No. 7418 (Cambridge, Massachusetts: National Bureau of Economic Research).

———, eds., 2005, *Other People's Money: Debt Denomination and Financial Stability in Emerging Market Economies* (Chicago: University of Chicago Press).

Eichengreen, Barry, and Peter Lindert, eds., 1989, *The International Debt Crisis in Historical Perspective* (Cambridge, Massachusetts: MIT Press).

Eichengreen, Barry, and Richard Portes, 1986, "Debt and Default in the 1930s: Causes and Consequences," *European Economic Review,* Vol. 30 (June), pp. 599–640.

Feder, Gershon, and Richard E. Just, 1977, "A Study of Debt Servicing Capacity Applying Logit Analysis," *Journal of Development Economics,* Vol. 4, No. 1, pp. 25–38.

Frankel, Jeffrey, and Andrew Rose, 1996, "Currency Crashes in Emerging Markets: An Empirical Treatment," *Journal of International Economics,* Vol. 41 (November), pp. 351–66.

Gavin, Michael, Ricardo Hausmann, Roberto Perotti, and Ernesto Talvi, 1996, "Managing Fiscal Policy in Latin America and the Caribbean: Volatility, Procyclicality, and Limited Creditworthiness," Working Paper No. 326 (Washington: Office of the Chief Economist, Inter-American Development Bank).

Greene, William H., 2000, *Econometric Analysis* (Upper Saddle River, New Jersey: Prentice Hall, 4th ed.).

Grossman, Herschel I., and Taejoon Hahn, 1999, "Sovereign Debt and Consumption Smoothing," *Journal of Monetary Economics,* Vol. 44 (August), pp. 149–58.

Grossman, Herschel I., and John B. Van Huyck, 1988, "Sovereign Debt as a Contingent Claim: Excusable Default, Repudiation, and Reputation," *American Economic Review,* Vol. 78 (December), pp. 1088–97.

Hu, Yen-Ting, Rudiger Kiesel, and William Perraudin, 2002, "The Estimation of Transition Matrices for Sovereign Credit Ratings," *Journal of Banking and Finance,* Vol. 26 (July), pp. 1386–1406.

Jorgensen, Erika, and Jeffrey Sachs, 1989, "Default and Renegotiation of Latin American Foreign Bonds in the Interwar Period," in *The International Debt Crisis in Historical Perspective,* ed. by B. Eichengreen and P. Lindert (Cambridge, Massachusetts: MIT Press), pp. 48–85.

Kose, M. Ayhan, Eswar Prasad, and Marco Terrones, 2006, "How Do Trade and Financial Integration Affect the Relationship Between Growth and Volatility?" *Journal of International Economics* (forthcoming).

Kose, M. Ayhan, and R. Riezman, 2001, "Trade Shocks and Macroeconomic Fluctuations in Africa," *Journal of Development Economics,* Vol. 65 (June), pp. 55–80.

Lindert, Peter H., and Peter J. Morton, 1989, "How Sovereign Debt Has Worked," in *Developing Country Debt and Economic Performance,* Vol. 1, ed. by Jeffrey Sachs (Chicago: University of Chicago Press).

Maddala, G. S., 1986, *Limited-Dependent and Qualitative Variables in Econometrics* (Cambridge, United Kingdom: Cambridge University Press).

———, and F. Nelson, 1974, "Maximum Likelihood Methods for Markets in Disequilibrium," *Econometrica,* Vol. 42, pp. 1013–30.

Mendoza, Enrique, 1995, "The Terms of Trade, the Real Exchange Rate, and Economic Fluctuations," *International Economic Review,* Vol. 36, No. 1, pp. 101–37.

———, 1997, "Terms-of-Trade Uncertainty and Economic Growth," *Journal of Development Economics,* Vol. 54 (December), pp. 323–56.

Obstfeld, Maurice, and Kenneth Rogoff, 1996, *Foundations of International Macroeconomics* (Cambridge, Massachusetts: MIT Press).

Ozler, Sule, 1993, "Have Commercial Banks Ignored History?" *American Economic Review,* Vol. 83 (June), pp. 608–20.

Pesaran, M. H., and B. Pesaran, 1997, *Working with Microfit 4: Microfit 4 User Manual* (Oxford: Oxford University Press).

Portes, Richard, and David Winter, 1980, "Disequilibrium Estimates for Consumption Goods Markets in Centrally Planned Economies," *Review of Economic Studies,* Vol. 47 (January), pp. 137–59.

Ramey, Garey, and Valerie Ramey, 1995, "Cross-Country Evidence on the Link Between Volatility and Growth," *American Economic Review,* Vol. 85 (December), pp. 1138–51.

Reinhart, Carmen M., 2002, "Default, Currency Crises, and Sovereign Credit Ratings," *World Bank Economic Review,* Vol. 16, No. 2, pp. 151–70.

———, Kenneth Rogoff, and Miguel Savastano, 2003, "Debt Intolerance," *Brookings Papers on Economic Activity: 1,* Brookings Institution, pp. 1–74.

Rose, Andrew K., 2002, "One Reason Countries Pay Their Debts: Renegotiation and International Trade," CEPR Discussion Paper No. 3157 (London: Centre for Economic Policy Research).

Sachs, Jeffrey, 1984, *Theoretical Issues in International Borrowing,* Princeton Studies in International Finance No. 54 (Princeton, New Jersey: Department of Economics, Princeton University).

———, 1989, *Developing Country Debt and Economic Performance,* Vol. 1 (Chicago: University of Chicago Press).

———, and Daniel Cohen, 1985, "LDC Borrowing with Default Risk," in *Internationales Bankgeschäft,* ed. by H.-J. Krümmel.

Sturzenegger, Federico and Jeromin Zettelmeyer, 2005, "Haircuts: Estimating Investor Losses in Sovereign Debt Restructurings, 1998–2005," IMF Working Paper 05/137 (Washington: International Monetary Fund).

Talvi, Ernesto, and Carlos Végh, 2002, "Tax Base Variability and Procyclical Fiscal Policy," NBER Working Paper No. 7499 (Cambridge, Massachusetts: National Bureau of Economic Research).