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Assessing Fiscal Sustainability Under Uncertainty

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Abstract

Unlike conventional fiscal sustainability assessments, the *Value-at-Risk* approach developed in this paper explicitly captures the contribution of key risk variables to public sector vulnerability. In an illustrative application to Ecuador, the *VaR* approach confirms a significant risk of government financial failure stemming from the volatility and comovements of the exchange rate, interest rates, oil prices, and output. Although dollarization has helped attenuate fiscal vulnerability, the volatility of sovereign spreads and of oil prices remain major sources of risk for Ecuador's public sector. The paper concludes with a discussion of policy implications, an evaluation of the methodology, and suggestions for future research.

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I. Introduction

In the past decade, an increasing number of capital-account crises have brought into focus the potential damage inflicted by a vulnerable public sector. While the nature and extent of the fiscal contribution to these crises have been the subject of investigation and debate,[2] it is widely recognized that in an open economy, a vulnerable fiscal position is often reflected in a vulnerable external position. Thus, policymakers, academic observers, financial institutions, and credit-rating agencies have become increasingly interested in gauging the vulnerability of the public sector, particularly in emerging market economies that are exposed to a high degree of capital mobility. Recently, in some of these countries, the concern of policymakers has translated into a formal legislative obligation for the government to prepare periodic evaluations of fiscal risk.[3] This paper represents an effort at developing and applying a comprehensive and objective method for estimating fiscal risk, in response to the widespread interest in crisis prevention.

Typically, evaluations of fiscal risk are predicated on assessments of fiscal sustainability conducted on the basis of medium- to long-term scenario calculations of public indebtedness—under plausible assumptions about future macroeconomic trends, supplemented with demographic and other environmental prospects. Scenario calculations can be further summarized in present-value terms. As a first approximation, fiscal sustainability is determined from the relation between the primary budget balance and key parameters (growth and interest rates) that affect public debt service obligations. The focus on present-value calculations or on summary indicators of fiscal sustainability have a clear limitation in ignoring the downside risk of adverse outcomes. The user is left with the task of ascertaining the margin of error (in both intensity and direction) around such scenarios or indicators. Not surprisingly, market analysts tend to adopt a rather cautious view by assuming a more conservative set of parameter values; by contrast, government officials have a vested interest in portraying a more sanguine image of the fiscal position based on more favorable assumptions.

Attempts at providing a comprehensive view of fiscal vulnerability have been limited to rather ad hoc ways of identifying major sources of risk, including in the form of unrecorded liabilities. An inventory of off-budget accounts, commitments, and contingent liabilities, in some cases subject to stylized stress tests or assumptions about probable outcomes, has been

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[2] On the fiscal contribution to currency crises in emerging markets, see, for example, Kopits (2000).

[3] In Brazil, under the Fiscal Responsibility Law of 2000, the authorities are required to prepare, as part of the yearly budgetary guidelines, an evaluation of fiscal risks, including: estimates of the quantitative impact (along with its probability) resulting from government decisions and other conditions; estimates of government guarantees and other contingent liabilities; and actuarial, financial, and economic assessment of public pensions, unemployment, and other employee insurancc schemes, and various contingency funds.

compiled for a diverse group of countries.[4] While informative, most of these estimates are neither sufficiently comprehensive, nor quantitatively objective to serve as an analytical framework for assessing sustainability under uncertainty.

This paper intends to move beyond the conventional approach, based on scenario calculations (even those enhanced with estimates of unrecorded liabilities) or other summary indicators, for assessing fiscal sustainability, and in particular, toward a more explicit and realistic way of accounting for the risks faced by the public sector. With this objective, it is proposed that a formal methodology, drawing on quantitative techniques—applied almost routinely to financial institutions[5]—be adopted to determine fiscal risk. Specifically, a *Value-at-Risk (VaR)* approach is developed with a view to applying it to the public sector in emerging markets.[6] In essence, this approach simulates a distribution of possible future financial conditions for the government and assesses the probability of financial failure, that may entail loss of access to financing. Ultimately, application of such an approach should be helpful for determining the fiscal adjustment that is necessary to compensate for risk and thus ensure fiscal sustainability at a prescribed confidence level.

The *VaR* approach should be most useful for assessing fiscal sustainability in emerging market economies, and, in particular, those endowed with nonrenewable resources. For one thing, these economies tend to be highly vulnerable to large-scale capital movements and have a greater need to understand and contain the sources of fiscal risk. For another, policymaking in many of these economies has been shaped by the mistaken belief—mainly during periods of high world commodity prices—that a virtually unlimited revenue flow from natural resources can support a high level of public expenditures without an adequate domestic nonresource tax effort. While these economies might be regarded as a limiting case, they underscore the importance of formulating a comprehensive and transparent quantitative method for assessing fiscal risk, as an important step to averting capital account crises.

The paper is organized as follows. Section II reviews key conceptual and practical aspects of the conventional approach to determining fiscal sustainability, and discusses its limitations. Section III explores the possible extension of the *VaR* methodology to public finances and formulates an analytical framework for that purpose. In Section IV, the approach is applied to the public sector of Ecuador, in view of this country's exposure to a variety of risk factors and availability of information on the government's balance sheet. Section V provides a discussion of tentative policy implications. The paper concludes with an evaluation of the *VaR* application to the public sector, along with suggestions for future research.

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[4] See the "fiscal-risk matrix," along with a "fiscal-hedge matrix," presented for several countries, in Polackova and Schick (2002).

[5] For a comprehensive treatment of the *VaR* approach, see Jorion (2001). An example of a recent application to the financial sector in South Africa can be found in Barnhill, Papapanagiotou, and Schumacher (2002).

[6] A *VaR* analysis of borrowing countries, as an integral part of IMF surveillance and crisis-prevention, was first suggested by Dornbusch (1998) in the aftermath of the Asian crisis.

II. Conventional Approach

Traditionally, the fiscal imbalance, or more broadly, the public sector borrowing requirement, incurred during the year has been regarded as a principal indicator of the fiscal contribution to macroeconomic disequilibria, reflected in the external current account. Similarly, early research on capital account crises pointed to the *flow* of monetized budget deficits as the root cause of such crises.[7] However, with increased openness in the capital account, the focus shifted to the fiscal position over an extended time horizon, that is, on the public debt *stock*. Indeed, it was recognized that the ability of the government to meet the intertemporal budget constraint can influence investor sentiment, so that difficulties in observing the constraint can lead to a speculative attack in the form of large-scale capital outflows, and eventually, loss of access to financial markets.[8]

Increasingly, therefore, fiscal vulnerability is seen as synonymous with fiscal sustainability, which usually is assessed in terms of public debt outstanding (rather than just the government income statement or budget outcome), possibly taking into account its maturity and currency composition. To evaluate fiscal sustainability, of course, public debt must be analyzed in a broad macroeconomic context, incorporating private saving propensity and future prospects for growth and interest rates. More recently, the stock of public debt outstanding has been supplemented with less obvious indicators of fiscal risk, such as the magnitude and nature of quasi-fiscal operations, government guarantees, contingent liabilities, and revenue structure.[9]

Assessment of fiscal sustainability rests in the integration of the flow of government balance and the stock of net indebtedness over a multiperiod horizon. As a starting point, the income statement of the consolidated public sector (encompassing the monetary and fiscal authorities) for period t can be stated simply as:

$$\begin{aligned} Y_t &\equiv T_t + N_t + S_t - G_t - rB_{t-1} \\ &\equiv Z_t + S_t - rB_{t-1} \ , \end{aligned} \tag{1}$$

where Y stands for the overall balance and Z is the primary (noninterest) balance. Revenue is the sum of: tax receipts less government transfers (T), determined by the level of economic activity, the tax structure, and administrative efficiency; net revenue from resource sales (N), as a function of production level, production cost, and resource price; and income from seignorage (S). Expenditure is comprised of primary outlays (G), made up of mandatory and

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[7] See the seminal work of Krugman (1979), and more recently, for example, Sachs, Tornell and Velasco (1996) and Summers (2000).

[8] See Calvo (1995) and Dooley (1998).

[9] For the role of anticipated fiscal imbalances (far in excess of recorded deficits and debt) in the Asian crisis, see Burnside, Eichenbaum and Rebelo (1999) and Corsetti, Pesenti and Roubini (1999).

discretionary payments on wages, goods and services,[10] and of interest payments, given by the product of the average rate of interest (r) and the net stock of public debt outstanding (B). In turn, the net debt consists of domestic liabilities, less assets, and of foreign liabilities, less assets. In addition, the public sector may hold a stock of net unfunded contingent liabilities (C) that arises in connection with social security programs, deposit insurance schemes, insurance for natural disasters, or other explicit and implicit government guarantees. Realization of C (i.e., conversion into B) is affected by the level of economic activity, demographic trends, effectiveness of bank supervision, adequacy of bank capitalization, and the frequency and severity of natural disasters.

The net worth of the public sector at $t = 0$ is derived from the comprehensive balance sheet expressed in terms of the present value of each component:[11]

$$\begin{aligned} W_0 &= PV(Z') - PV(\Delta C) - B_0 \\ &= \sum_{t=0}^{\infty}(1+r)^{-t}Z'_t - \sum_{t=0}^{\infty}(1+r)^{-t}\gamma_t \Delta C_t - \sum_{t=0}^{\infty}(1+r)^{-t}\Delta B_t \ , \end{aligned} \tag{2}$$

where Z' is defined as the primary balance generated by the existing fiscal system, comprised of the tax structure and mandatory spending programs prevailing in $t = 0$, that is, excluding the effect of any unanticipated discretionary action or adjustment in a future period. In addition, the flow of net unfunded contingent liabilities (ΔC) is subject to the probability of realizing the contingency, expressed by parameter $0 \leq \gamma \leq 1$, in time t.[12] The outstanding debt stock is replaced by the discounted future net amortization schedule (ΔB).

Further, (2) can be summarized in a general functional form as

$$W = PV(q, r_H, r_F, f, p_N, p) \ , \tag{3}$$

indicating that the public sector net worth will depend on the present and future level of output (q), interest rates at home and abroad (r_H, r_F), the exchange rate (f), world commodity prices (p_N), and the domestic price level (p).

If $W \geq 0$, the public sector is deemed to be *solvent* and the intertemporal budget constraint is fully satisfied. In a riskless environment characterized by certainty of expectations, the

[10] Mandatory expenditures are predetermined by multiyear government programs or by revenue earmarking. Discretionary expenditures are those over which the government has complete flexibility to determine from year to year.

[11] In the context of (3), Z reflects the tax system and primary outlays under mandatory programs. Thus W excludes all discretionary expenditures, occasional levies and seignorage revenue, or any other flows that can be regarded as compensatory or induced to meet the intertemporal budget constraint.

[12] In reality, γ summarizes the probability distribution of the occurrence of the contingency in any given time period.

government's financial position is sustainable if the present value of the expected future fiscal surpluses is greater than or equal to the current debt outstanding. However, a major shortcoming of this statement is that it refers to expected outcomes, without accounting for downside risk, including the possibility that the government may lose access to financing if lenders' perception of W becoming negative reaches an unacceptable level.

Alternatively, the intertemporal budget constraint can be derived from linking the change in the net debt position and the income statement (for simplicity, ignoring contingent liabilities and seignorage revenue) in period t:

$$B_t \equiv B_{t-1} + rB_{t-1} - Z_t \ , \tag{4}$$

Stated in proportion to GDP, by advancing period by period, iterating sequentially, and assuming that the primary surplus grows at the same rate as GDP—all expressed in real terms—*solvency* obtains if:

$$b_{t-1} = \sum_{j=0}^{\infty} \left(\frac{1+g}{1+r}\right)^j z_{t+j}, \tag{5}$$

Capturing the debt dynamics in this manner allows a solution for the permanent primary surplus needed to maintain the net debt-GDP ratio stable (or nonincreasing) over time:

$$z^* \geq \left(\frac{r-g}{1+g}\right) b_{t-1}, \tag{6}$$

which is the conventionally accepted condition for fiscal *sustainability*.[13] Again, this approach focuses on expected outcomes and fails to adequately and systematically quantify the probability of more adverse outcomes.

Notwithstanding the advantages of estimating public sector net worth in equation (2),[14] condition (6) is ordinarily used to determine sustainability—or, in fact, stability of the debt ratio—because of minimal data requirements.[15] The latter provides a reasonable approximation of the required additional fiscal adjustment for advanced economies, where interest rates and potential growth rates are relatively stable over time. Accordingly, there

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[13] See Buiter (1985). As an alternative, according to Blanchard and others (1990), a sustainable position obtains if the debt ratio eventually converges to its initial level. Condition (6) can be expanded to incorporate the effect of the real exchange rate by disaggregating debt and output in terms of tradables vs. nontradables; see Calvo, Izquierdo, and Talvi (2002).

[14] See the arguments advanced in Easterly (1999) for using net worth to gauge the need for fiscal adjustment.

[15] See, for example, the calculations for industrial countries over different time horizons in Blanchard and others (1990).

have been useful (including some model-based) attempts at determining fiscal sustainability in European economies, by tracking major fiscal aggregates (government expenditure, tax revenue, debt) over a medium- to long-term horizon.[16]

For developing countries, by comparison, the scope and nature of fiscal sustainability exercises have been uneven. Apart from medium-term scenario calculations geared primarily at determining the path of the external current account and indebtedness—conducted in the context of IMF surveillance or of IMF-supported adjustment programs—there are relatively few comprehensive fiscal sustainability assessments. Application of (6) for assessing fiscal sustainability, especially in Latin America, has become relatively common.[17] Estimates of the comprehensive public sector balance sheet, as stated in (2), are available for only a few of these countries.[18]

Whereas this approach provides some indication of the vulnerability of the public sector, the wide margin of uncertainty inherent in scenario calculations and in summary indicators impairs the usefulness of (2) and (6) for evaluating fiscal risk. This is a major shortcoming in the case of emerging market economies that may be particularly vulnerable to sudden shifts in market sentiment in a volatile economic and financial environment. Attempts to correct for this deficiency by performing sensitivity tests with respect to marginal shifts in key risk variables (without accounting for correlations), or to arbitrary shocks, are of limited value.[19] Similarly, calculating a risk-weighted public sector balance sheet with predetermined weights would be unrealistic.[20] Instead, it is necessary to develop an approach that captures the distribution of potential public sector net worth by valuing the main categories of assets and liabilities in (3), incorporating an explicit quantification of the underlying sources of risk.

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[16] See the papers in Banca d'Italia (2000), undertaken mainly with the purpose of determining the compatibility of fiscal policy with the reference values under the Economic and Monetary Union, in the light of future macroeconomic and demographic prospects.

[17] Examples can be found in Tanner and Ramos (2001) for Brazil, and in Santaella (2001) for Mexico. Less comprehensive calculations (limited mainly to social security finances) are available for other Latin American countries in Talvi and Vegh (2000).

[18] See Echeverry and others (1999) for Colombia; Garcia, Rodriguez, and Villasmil (1999) for Venezuela; and Arteta and Samaniego (2001) for Ecuador.

[19] In the formulation of a standardized framework for assessing external and fiscal sustainability by the Fund staff, it is acknowledged that "assessments of sustainability are probabilistic, since one can normally envisage some states of the world under which a country's debt would be sustainable and others on which it would not. But the proposed framework does not supply these probabilities explicitly; rather, it traces the implications of alternative scenarios and leaves the user to determine the probabilities.... The framework also proposes a set of sensitivity tests, but further work will be necessary to settle on a precise calibration" (see International Monetary Fund, 2002, p. 25). The sensitivity analysis suggested for baseline projections of the public debt ratio include: historical averages, as well as one and two standard-deviation shocks in the growth rate, rate of interest, and primary balance; a 30 percent devaluation; and a 10 percent increase in debt-creating capital inflows.

[20] In this vein, application of the Basle weights to public sector assets would be an arbitrary exercise. For a critique of the proposed new Basel capital requirements for banking institutions, especially in emerging market economies, see Barnhill and Gleason (2002).

III. *VALUE-AT-RISK* APPROACH

Although periodic asset bubbles and bank failures have been around for a very long time, vulnerability to the ensuing crises in this interdependent world has increased significantly in recent years. Increased risk manifests, above all, in highly volatile exchange rates, interest rates, inflation rate, output, commodity prices, and asset prices. Identification of these environmental risks and measurement of their volatility and correlation (mutually as well as with ordinary credit risk) is relatively novel.[21] In this regard, the *VaR* concept represents a major innovation for improving risk measurement and management. By now, *VaR* is widely used in portfolio and financial institution risk assessment.

The *VaR* of a portfolio or a balance sheet summarizes "the worst possible loss over a target horizon with a given level of confidence."[22] Specifically, it is a numerical estimate of the potential loss over a finite period (e.g., one percent probability, or 99 percent confidence level, of losing ten million dollars in a given day). Various analytical and simulation modeling techniques are used to estimate the distribution of future portfolio values and to calculate the downside risk of the portfolio. In the most general form, the basis for calculating the *VaR* is the variance of the return on the portfolio

$$\sigma_p^2 = w'\sum w, \tag{7}$$

where w = vector of weights for the various securities in the portfolio,
w' = transposed vector of weights in the portfolio, and
$\sum$ = variance-covariance matrix of R returns on securities in the portfolio.

Equation (7) is the essence of the *VaR* analysis; it constitutes the envelope for the volatility of, and correlation among, various risk variables. To implement *VaR* it is necessary to specify the determination of each risk variable, including the relationship among these variables over time. Depending on the specification of the risk variables, which impose varying data and calculation requirements, the *VaR* can be calculated according to either local-valuation or full-valuation methods.

The delta-normal approach is the most commonly used *local-valuation method*. This consists of calculating the maximum potential loss in the portfolio over a relatively short predetermined time period, under the rather convenient assumption that all risk variables are normally distributed. Hence, from (7) we can readily calculate the entire portfolio value at risk:

$$VaR_p = \alpha\sigma_p W, \tag{8}$$

[21] See, for example, Smithson and Smith (1995) and Fridson, Garman, and Wu (1997).

[22] See the definition in Jorion (2001, p. 22).

where α = standard normal deviate (e.g., 1.65 for the 95 percent confidence level), and
W = initial portfolio value.

By its very nature, the delta-normal approach is mainly appropriate for portfolios of financial institutions exposed to limited sources of risk and over a short time horizon.[23] Application of this method to the government would require: valuation of its portfolio of assets and liabilities; decomposition of these assets and liabilities into a set of primitive securities (e.g., domestic and foreign zero-coupon bonds, equity securities, spot positions in foreign currency, commodities, etc.); and estimation of the variance and covariance of returns on these primitive securities constrained by the assumption of normal distribution.

By contrast, *full-valuation methods* are far more versatile and realistic, as they are open to a variety of specifications for risk variables. In the first place, these methods call for the simulation of potential future financial and economic environments, including all of the required stochastic variables used to value assets and liabilities, over as long a time-step as necessary.[24] Subsequently, the full portfolio is revalued in the simulated environment. After many repetitions of the simulation, a distribution of portfolio values is created and analyzed to determine the value at risk at a given confidence level. Such simulations allow for non-normal distributions of risk variables, nonlinear option-like payoffs, and time-decay effects.[25]

Therefore, by their very nature, full-valuation methods, whether in the form of historical or Monte Carlo simulations, are more accurate than local-valuation methods. Under the historical method, the variance and covariance of the risk variables are calculated on the basis of historical time series, while the Monte Carlo method incorporates analytical models that specify the manner in which variables change over time. For these reasons the full-valuation Monte Carlo method appears to be the most appropriate to calculate the *VaR* of the public sector.

For the public sector, the approach can be summarized by the net worth equation (3), subject to *VaR*, over a given time horizon and subject to a confidence level, to estimate the risk-adjusted net worth:

$$W^* = PV\left(q, r_H, r_F, f, p_N, p\right) - VaR\,(W) \ . \tag{9}$$

[23] For a discussion of alternative applications, see Jorion (2001) and Hull (2000). The mathematics associated with the delta-normal method in assessing central bank vulnerability can be found in Blejer and Schumacher (1998).

[24] Simulation of the financial environment can be viewed as a random draw from an n-dimensional joint density function, where n is the number of stochastic variables.

[25] For an extension of a portfolio simulation approach for assessing integrated market and credit risk to estimate bank capital requirements and compare them to those required under the proposed new Basel Capital accord in the case of Latin America, see Barnhill and Handorf (2002).

The critical ingredient for calculating the *VaR* is the determination of the underlying variance and covariance of key risk variables in Σ: the term structure of the interest rate; the volatility of prices and quantities (domestic price level, exchange rate, output, etc.); the return on government assets (mainly state-owned enterprises); the price of nonrenewable resources (world price of oil); and the determinants of the residual primary government balance. Before proceeding with the actual application, let us review the specification of each risk variable.

For simulating the stochastic term structure of *interest rates* (i.e., interest rates denominated in domestic and foreign currency), it is assumed that interest rates follow a time-dependent mean-reversion process.[26] In this process, the risk-neutral[27] change in the continuously compounded short-term interest rate is

$$\Delta r = a\,(\frac{\theta(t)}{a} - r)\,\Delta t + \sigma\Delta z\,, \tag{10}$$

where a = rate at which r reverts to its long-term mean,
θ = parameter for consistency with the initial term structure,
σ = instantaneous standard deviation of r,
$\Delta z = \varphi\sqrt{\Delta t}$ = movement in term structure or r (Wiener process), and
φ = random draw from a standardized normal distribution.

The mean reversion and volatility rates can be estimated from a time series of short-term interest rates or as implied from cap and floor prices. Once the risk-free term structure (e.g., on U.S. government securities) has been estimated, then other risky term structures are modeled as a stochastic lognormal spread over risk-free structure. This procedure ensures that simulated rate spreads are always positive and that the simulated term structures are approximately arbitrage free.[28]

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[26] See the extension of the Vasicek model for stochastic risk-free interest rates in Hull and White (1994).

[27] In a risk-neutral world, investors require no compensation for risk and the expected return on all assets is the risk-free interest rate.

[28] For a fuller discussion of modeling risk-free and risky interest rate term structures, along with the application of a diffusion-based methodology for assessing the *VaR* of a portfolio of fixed-income securities (with correlated interest rate, interest yield spread, exchange rate, and credit risk), see Barnhill and Maxwell (2002).

For the simulation of most *other financial and economic risk variables* (rates of return, exchange rate, prices, output), we adopt an approach often used for simulating asset prices and returns. Specifically, the value of the variable S is assumed to follow a geometric Brownian motion, where the expected growth rate (m) and volatility (σ) are constant.[29] The expected growth rate is equal to the expected return on the asset (μ) minus its dividend yield (d). For a discrete time step Δt, it can be shown that

$$S + \Delta S = S \exp\left[\left(m - \frac{\sigma^2}{2}\right)\Delta t + \sigma\varphi\sqrt{\Delta t}\right]. \tag{11}$$

Consequently, the rate of return on the equity market (k) is estimated as

$$k = ln\left[(S + \Delta S) / S\right] + d, \tag{12}$$

and the rate of return on the ith state-owned enterprise can be represented as

$$k_i = r + \beta_i (k - r) + \sigma_i \Delta z, \tag{13}$$

where r = risk-free interest rate,
β_i = systemic risk faced by the enterprise, and
σ_i = firm-specific standard deviation of the return on equity.

The value of the state-owned enterprises at time Δt is:

$$V_{\Delta t} = V_0 e^{k_i \Delta t}. \tag{14}$$

And given the distribution of possible future returns in k_i, the future value of these enterprises is stochastic as well.

For simulating the *price of nonrenewable resources*, it is convenient to utilize an approach based on both a variable long-term equilibrium price and short-term deviations from this price, allowing for correlation between long-term and short-term prices. This approach, developed to value future oil production,[30] is chosen for four reasons. First, when properly calibrated, it has been shown to provide reliable estimates of forward oil prices. Second, the concept of a long-run equilibrium price and a short-run deviation that decays over time is consistent with ordinarily assumed oil price developments. Third, forward oil prices thus calculated can be multiplied by production forecasts to obtain a future cash flow stream; in turn, this can then be discounted back to arrive at the present value for the oil reserves. Fourth, after simulating the correlated long-run equilibrium price and short-term deviations,

[29] See, for example, Hull (2000, p. 408).

[30] See Schwartz and Smith (2000).

we can apply a similar methodology to estimate a distribution of future values for the projected oil production. Under this approach, the current market price for a futures contract with time T until maturity is derived as follows:

$$ln(p_{NT,0}) = e^{kT}x_0 + \varepsilon_0 + A(T), \quad (15)$$

where

$$A(T) = u_{\varepsilon}^{*}T - (1-e^{-kT})\frac{\lambda_{\chi}}{\kappa} + 2(1-e^{-kT})\frac{\rho_{\chi\varepsilon}\sigma_{\chi}\sigma_{\varepsilon}}{\kappa} + \frac{1}{2}(1-e^{-2kT})\frac{\sigma_{\chi}^{2}}{2\kappa} + \sigma_{\varepsilon}^{2T}$$

and x_t = zero-reverting short-term deviation in prices (Ornstein-Uhlenbeck process),
ε_t = equilibrium price level,
k = expected rate of decay of short-term price deviations,
σ_x = standard deviation of short-term price deviations,
λ_x = short-term risk premium,
σ_{ε} = standard deviation of equilibrium price,
μ_{ε}^{*} = equilibrium risk-neutral drift rate, and
$\rho_{x\varepsilon}$ = correlation of equilibrium price changes and short-run price deviations.

Therefore, the present value of the production of a nonrenewable resource, such as oil, can be represented as

$$VN = \sum_{t=0}^{\infty}(1+r)^{-t}N_t(p_{Nt,0} - c_{Nt}), \quad (16)$$

where N_t = quantity produced, and
c_{Nt} = constant production cost per unit of output.

All risk variables are simulated as correlated stochastic variables. This procedure requires the specification of correlations between each of the n stochastic variables.[31] Subsequently, n independent random samples x are drawn from standardized normal distributions, which allows for the calculation of a set of correlated random error terms for the n stochastic variables. For a bivariate normal distribution,

$$\varphi_1 = x_1, \quad (17)$$

$$\varphi_2 = \rho x_1 + x_2\sqrt{1-\rho^2}\ , \quad (18)$$

[31] See Hull (2000) for a procedure derived for an n-variate normal distribution.

where x_1, x_2 = independent random samples from standardized normal distributions,
ρ = correlation between the two stochastic variables, and
φ_1, φ_2 = random drawings from a standardized bivariate normal distribution.

It can be shown that the simulated volatilities and correlations for all of the stochastic variables closely match values estimated from time series data.[32]

In the next section, this analysis is applied to valuing government assets and liabilities, and for assessing the probability that the government faces default—usually accompanied by loss of access to financial markets—as its net worth becomes negative.[33] This approach is similar to estimating default risk for private firms in a contingent-claims-analysis framework.[34]

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[32] The current application of *VaR* to the government balance sheet abstracts from counterparty credit risk. However, Barnhill, Papapanagiotou, and Schumacher (2002) have shown that it is possible to simulate correlated market and credit risk and undertake risk assessments of banks using a contingent-claims framework. In principle, this can be extended to conduct a simultaneous government and banking sector risk analysis.

[33] In practice, firms are observed to often default before the value of the firm falls below the value of the outstanding debt (i.e., before the firm's net worth becomes negative). Although less frequently, a solvent government may default in a liquidity crisis.

[34] See Black and Scholes (1973) and, more explicitly, Merton (1974). Shareholders hold a call option on the firm and its debt/value ratio is a measure of how far the call option is in the money. In addition to a number of standard-efficient-market assumptions, this framework assumes that the dynamics for the value of the firm, V, through time can be described by a diffusion-type stochastic process with the differential equation

$$\Delta V = (\alpha V - C)\,\Delta t + \sigma V dz\,, \tag{19}$$

where: α = instantaneous expected rate of return on the firm per unit time,
C = payout by the firm per unit of time to shareholders or liability holders,
σ^2 = instantaneous variance of return on the firm per unit of time, and
Δz = movement under a standard Gauss-Wiener process.

IV. Application to Ecuador

Among emerging market economies, the selection of a country episode for testing the *VaR* approach is dictated primarily by data availability. In addition to high-frequency macroeconomic statistics and basic data on the general government, the methodology rests on the present value of public sector assets and liabilities. Another key selection criterion is exposure of the public sector to an environment characterized by sufficient variety and level of risk.

The case of Ecuador seems to fit both criteria, given the availability of the public sector balance sheet, and in view of the country's exposure to a wide range of risk variables. While well endowed with oil and other natural resources, Ecuador has suffered concurrently since 1998, currency, banking, and debt crises, plus natural disasters (primarily *El Niño*). The discounted future government revenue from oil reserves is estimated to reach nearly twice the level of trend GDP; equally, the sum of both recorded and contingent public liabilities stands close to that level. In addition, Ecuador has taken a major step by fully dollarizing the economy in early 2000. In all, this rich experience provides an excellent case study for applying the *VaR* approach, and in that context, for ascertaining the effect of each risk variable, including the likely consequences of dollarization, on the balance sheet of the public sector.

The benchmark for the *VaR* analysis consists of estimates of the present value of major components of the balance sheet of the consolidated public sector for 2000.[35] Variances and covariances for all stochastic variables (including domestic inflation, exchange rate, interest rates, oil price, output) were calculated according to the specifications outlined in the preceding section.[36] With these ingredients, it was feasible to compute indicators of dispersion around the present value of each major category of assets and liabilities, consisting of recorded financial and real assets, financial liabilities, expected revenue from oil reserves and various other contingent assets as well as contingent liabilities (associated with public pensions, banking, natural disasters). This permits the derivation of the risk-adjusted net worth in equation (9).

Reliance on the balance sheet alone for calculating fiscal sustainability would overstate the government's latitude for undertaking a fiscal adjustment with discretionary measures (tax increases and/or primary expenditure cuts) and would ignore the inherent rigidity of the fiscal structure. In fact, in Ecuador, the authorities have been constrained by a high proportion of mandatory outlays as a result of extensive revenue earmarking.[37] This requires enhancing the

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[35] The principal data source for the public sector balance sheet is Arteta and Samaniego (2001).

[36] For a more detailed discussion, see the Appendix.

[37] More than one half of revenue is estimated to be constitutionally or legally earmarked for primary expenditures by specific government institutions and/or purposes—in addition to payroll contributions for social security, which, by their very nature, are fully earmarked. In practice, actual earmarking falls short of the prescribed proportions because of considerable fiscal stress.

balance sheet estimates with the present value of the residual primary balance, given by the projection of tax revenues and primary expenditures unrelated to items identified in the balance sheet. The resulting discounted residual balance is then subject to relevant risk variables. Assuming that the government adheres fully to legal and constitutional earmarking, both revenue and primary expenditures are driven by the volatility of non-oil GDP and its comovement with other risk variables. The resulting procyclicality—often exacerbated by discretionary action—of the fiscal stance has been widely observed in Latin America over the past decades.[38]

In view of its versatility, the full-valuation Monte Carlo method is applied for calculating the *VaR* of the public sector over a time step or increment of one year. Unlike investment portfolios or financial institutions, which may be vulnerable over a relatively short time horizon,[39] fiscal vulnerability to crises can be protracted over time. Thus, for the public sector, risk assessment should span a longer period. The one-year time step adopted in the present exercise can be regarded as a minimum period from the perspective of fiscal policy.

Estimates of *VaR* indicate that in 2000, in the wake of the multiple crises experienced in the late 1990s, Ecuador faced considerable fiscal vulnerability. In 2000, absent risk, the net worth of Ecuador's public sector had reached US$8 billion. However, on a risk-adjusted basis, the net worth is estimated at a negative value of US$21 billion with 5 percent probability (Table 1). Stated differently, at 95 confidence level, the *VaR* of the public sector is around US$29 billion (given by the difference between the mean and the risk-adjusted value). The balance sheet components whose volatility has the largest potential impact on net worth include: income from petroleum reserves, profits from state-owned enterprises, outstanding external liabilities, and net liabilities of the public pension system. Other assets and liabilities seem to be relatively less exposed to risk.

Without the residual (non-oil, nonpension) primary balance, the net worth would stand at some US$12 ½ billion, assuming complete flexibility in applying discretionary measures—in the absence of revenue earmarking. Although the residual balance contributes significantly to the risk-adjusted net worth, in fact the *VaR* is barely US$1½ billion more favorable by excluding, rather than including, the residual balance, at 95 percent confidence level (Table 1). These two variants are illustrated by the distributions of potential outcomes, including the outcome of insolvency (i.e., where net worth is zero) at 35 percent probability incorporating the residual primary balance and 24 percent upon excluding it (Figure 1).

Simulations of the risk-adjusted net worth indicate the relative importance of each major source of fiscal risk, as reflected in estimates of risk-adjusted net worth or of *VaR* at various levels of probability (Table 2). Against the baseline estimates, three basic simulations are

[38] For evidence of procyclical fiscal behavior in Latin America, aggravating the effects of the volatility of output, commodity prices, and capital flows, see Gavin and others (1996).

[39] For trading portfolios, with good liquidity position, often a one-day time step is utilized. Alternatively, for banks with less liquid portfolios a time step of up to one year is more appropriate.

presented (with and without the residual primary balance). Simulation 1 is meant to capture the effect of official dollarization of the economy (actually phased in during the first quarter of 2000) by suppressing the volatility of the exchange rate and the domestic price level, and setting the volatility of the domestic currency interest rate equal to that of the foreign currency interest rate. In simulation 2, besides dollarization, the volatility of interest rates is set equal to zero. Alternatively, in simulation 3, the volatility of oil prices is set to zero.

Simulations, based on ex ante measures of risk variables, corroborate that the principal sources of fiscal risk for Ecuador were the volatility in the interest yield spread, the exchange rate, and oil prices, as well as their comovements. Dollarization is estimated to have reduced *VaR* about US$3 billion (US$2 billion without the residual balance), with 95 percent confidence level. If, in addition, Ecuador had managed to eliminate volatility in the spread, risk would have fallen by as much as US$14 billion. Alternatively, the hypothetical elimination of oil price volatility would have contributed, instead, to a US$6 billion decline in risk (US$5 billion absent the residual balance) (Table 2). The simulation results can be seen graphically, reflecting an increased bunching of probability distributions for simulations 1, 3, and 2, respectively (Figure 2).

As a further check on the effect of dollarization, an ex post simulation is conducted for 2000, on the basis of post-dollarization data for risk variables. The simulated decline in *VaR* is at least twice as large with the ex post data than with ex ante data, suggesting a possible overstatement of the *VaR* in the ex ante simulation (Table 2). This result may be attributed in part to the slightly lower volatility in the underlying risk variables during the relatively more tranquil period following dollarization.[40] While interesting, the reliability of the ex post simulation must be tempered by the short time period over which the volatility and correlation of stochastic variables are estimated.

[40] Since 2000:3, the standard deviation of the listed variables is as follows (estimates for the period up to 1999:4 are shown in parentheses): yield spread, 0.07 (0.08); oil price, 0.26 (0.24); and non-oil GDP, 0.02 (0.04).

Table 1. Ecuador: Risk-Adjusted Balance Sheet of the Public Sector, 2000
(In billions of U.S. dollars)

Assets	Present Value (Mean) 1/	Standard Deviation	Maximum Value	Minimum Value	Risk-Adjusted Value 2/	Liabilities	Present Value (Mean) 1/	Standard Deviation	Maximum Value	Minimum Value	Risk-Adjusted Value 2/
Recorded assets						Recorded liabilities					
Foreign exchange reserves	1.4	--	--	--	1.4	Short-term liabilities	0.6	0.1	1.1	0.3	0.8
Other current assets	2.1	0.4	4.0	1.1	1.6	External liabilities	10.1	2.1	12.8	1.4	12.3
Fixed assets	1.7	0.3	3.4	0.9	1.3	Domestic liabilities	3.7	0.7	7.6	1.8	5.0
Other assets	0.1	0.0	0.3	0.1	0.1	Deficit guarantee obligations	0.1	0.0	0.1	0.0	0.1
Contingent assets						Contingent liabilities					
Petroleum reserves	33.7	12.2	92.2	2.1	14.0	Natural disasters (*El Niño*)	2.1	0.4	3.4	0.6	2.7
Biodiversity	2.4	0.6	4.3	0.3	1.3	Deposit guarantee fund	2.0	0.4	4.6	0.8	2.8
CO_2 capture	1.7	0.4	2.9	0.2	0.9	Public pensions (IESS)	15.5	6.4	42.8	0.4	25.7
State-owned enterprises	4.3	2.5	31.5	0.6	1.6						
Total assets	47.5	11.8	103.5	13.0	29.1	**Total liabilities**	35.1	9.9	72.1	6.3	49.8
Residual primary balance	-4.6	1.5	-0.5	-11.4	-7.2	**Net worth** 3/	7.9	18.2	93.0	-55.0	-21.2
							(12.4)	(17.0)	(95.2)	(-43.5)	(-15.1)

1/ Present value based on Arteta and Samaniego (2001), except for residual primary balance.

2/ Difference between present value and *VaR* for each category of assets or liabilities. Values under each category are not additive for calculating risk-adjusted totals or net worth. Calculated at five percent probability (i.e., 95 percent confidence level).

3/ Excluding residual primary balance shown in parentheses.

Table 2. Ecuador: Simulations of Risk-Adjusted Public Sector Net Worth, 2000 1/
(In billions of U.S. dollars, unless otherwise noted)

	Risk Variables				Present Value (Mean)	Standard Deviation	Maximum Value	Minimum Value	Risk-Adjusted Value		Probability of Insolvency 2/ (Percent)
	Exchange Rate	Interest Rate	Oil Price	Other					1 Percent Probability	5 Percent Probability	
Ex ante											
Baseline	X	X	X	X	7.9	18.2	93.0	-55.0	-32.7	-21.2	35
					(12.4)	(17.0)	(95.2)	(-43.5)	(-25.3)	(-15.1)	(24)
Simulation 1		X	X	X	8.2	16.7	84.2	-44.6	-27.3	-18.1	32
					(12.1)	(16.0)	(93.3)	(-29.5)	(-21.7)	(-13.1)	(23)
Simulation 2			X	X	7.4	10.1	61.5	-19.8	-12.0	-7.6	26
					(12.5)	(9.5)	(55.2)	(-13.0)	(-5.5)	(-1.4)	(7)
Simulation 3		X		X	8.0	13.3	51.5	-37.8	-25.0	-15.4	26
					(12.6)	(12.5)	(50.5)	(-28.0)	(-18.8)	(-9.4)	(15)
Ex post											
Simulation 1		X	X	X	7.1	12.7	61.3	-34.5	-21.5	-13.4	30
					(11.5)	(12.2)	(66.2)	(-26.3)	(-16.3)	(-8.5)	(17)

1/ All simulations are computed for net worth including the residual primary balance; net worth excluding the residual balance is shown in parentheses. For the baseline, calculations for each category of assets or liabilities are provided in Table 1. Ex ante simulations are based on risk variables with data for 1995:1–1999:4 and ex post simulations are performed with data for period 2000:3–2002:4 (see Appendix).

2/ Probability at which the risk-adjusted net worth is equivalent to zero.

Figure 1. Ecuador: Probability Distribution of Public Sector Net Worth, 2000

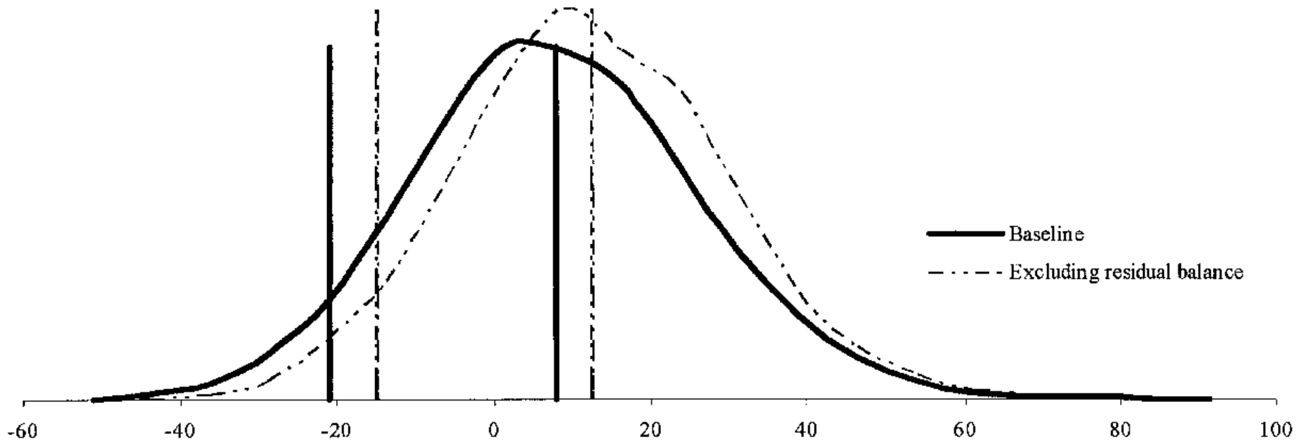
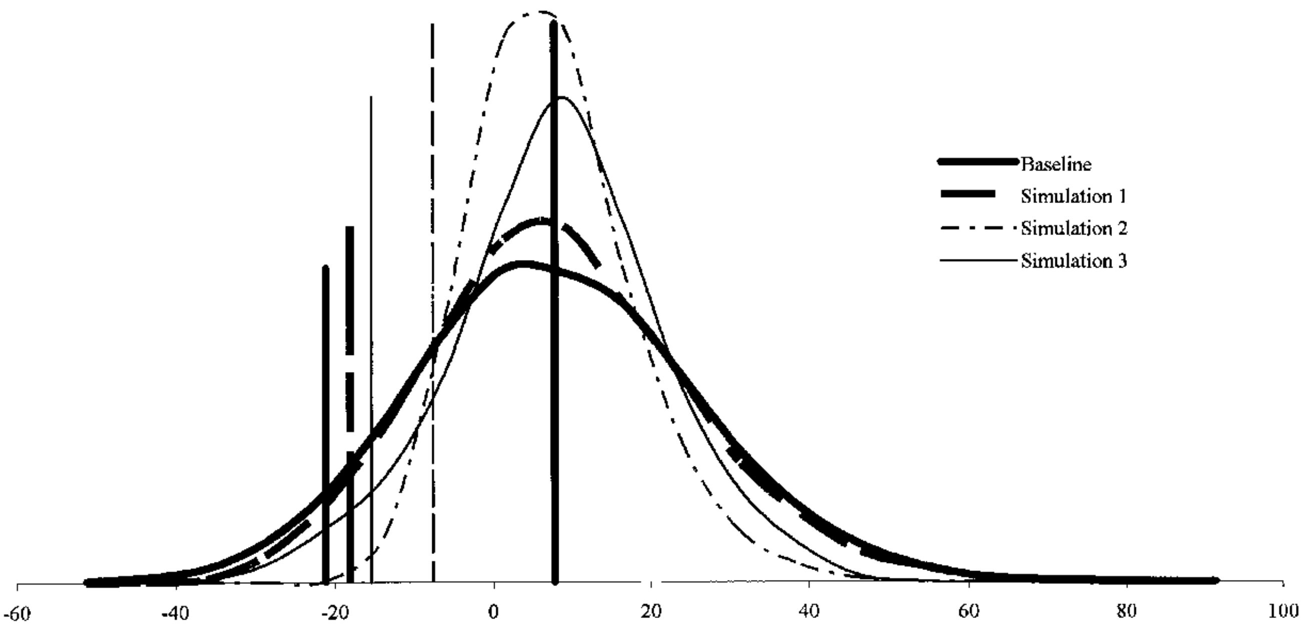


Figure 2. Ecuador: Probability Distribution of Public Sector Net Worth Simulations, 2000



V. Policy Implications

The *VaR* analysis confirms that conventional fiscal sustainability calculations and indicators, even when subject to various stress tests, provide no more than a first approximation of the vulnerability of the public sector to financial crises. Indeed, application of the *VaR* approach to a comprehensive public sector balance sheet indicates that conventional scenario-based calculations and indicators can understate significantly the fiscal vulnerability faced by governments in emerging markets. The findings suggest that in Ecuador the volatility in the sovereign yield spread is a major source of fiscal vulnerability. In fact, the contribution of spread volatility to fiscal risk, and, to a lesser extent, the contribution of exchange rate volatility, exceed the effect of oil price volatility—the only truly exogenous source of risk that lies beyond the influence of the authorities. In addition, fiscal rigidities tend to enhance the contribution of output volatility.

A central implication of these results is that emerging market economies with attributes comparable to those of Ecuador, namely, highly indebted, even if well endowed with nonrenewable resources, should implement a strategy aimed at reducing the country risk premium and at improving the risk-adjusted net worth position of the public sector. Clearly, a significant fall in the risk premium, reflected in the level and volatility of the yield spread, would be conducive to a virtuous cycle of macroeconomic stability and sustained growth. In early 2003, the authorities of Ecuador announced important initiatives toward that strategic objective, in line with the following specific implications of the above findings.[41]

First, emerging market economies should avoid accumulating beyond a certain stock of government liabilities—especially in the form of short-term debt contracted in foreign currency, at variable interest rates, resulting in maturity and currency mismatches that can give rise to debt-servicing problems. As part of prudent public debt management, they should resist the proliferation of guarantees and the accumulation of unfunded contingent liabilities. Accordingly, Ecuador has set a medium-term limit on the debt-GDP ratio,[42] and announced steps to contain the buildup of contingent liabilities—partly through reforming the social security system and restoring the soundness of the banking sector.

Second, emerging market economies should be ready to take policy action commensurate with convergence to a solvent fiscal position, by strengthening the residual primary balance position highlighted in the above exercise. Adjustment measures should, as much as possible, entail trimming nonproductive expenditure programs and rationalizing the tax system, including elimination of revenue earmarking—which constitutes not only a built-in source of procyclicality, but also a severe impediment to fiscal adjustment. Ecuador's authorities are

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[41] These policy commitments (noted below) are documented in International Monetary Fund (2003).

[42] Although ordinarily the target limit on the public debt is expressed in proportion to GDP (40 percent in the case of Ecuador), the ratio of debt to tax receipts reflects more accurately the government's debt-servicing capacity. The argument for measuring the public debt ratio in terms of tax revenue rests on the much higher macroeconomic volatility in Latin America than, for instance, in the OECD; see Hausmann (2002).

committed to launching major steps in the near future on these fronts, thus addressing the adjustment requirement illustrated by the above estimates.[43]

Third, the yield spread on government paper is an endogenous source of risk that can be reduced not only by restraining the buildup of actual and contingent liabilities, but more important, by strengthening the institutional framework.[44] Slow progress in this regard has been a major stumbling block in Ecuador in the past, preventing a decline in the mean and variance of sovereign spread after dollarization.[45] The recent introduction of a transparent and rules-based policy framework represents a major step in institution-building in the fiscal area.[46] If properly implemented, this framework—supported by key structural reform measures, including in the financial sector—should contribute to a significant decline in the risk premium and to sustained growth.

Fourth, a related implication is that, by itself, dollarization tends to have a relatively modest impact in reducing fiscal vulnerability. The evidence from simulation 1 (whether ex ante or ex post) indicates that after dollarization, Ecuador still faces a large negative risk-adjusted net worth in the public sector. While abstaining from a generalization to other emerging market economies, this result can certainly be interpreted as a cautionary note that dollarization needs to be accompanied by the establishment of a credible institutional framework and adherence to fiscal discipline.

Finally, policymaking in natural-resource endowed economies was often predicated on the notion that significant reserves of oil or other nonrenewable commodities, in some way, compensate for fiscal profligacy. This notion is, of course, illusory in the light of the adverse effect of high volatility in commodity prices on fiscal sustainability. As oil price fluctuations are beyond the control of the authorities, their domestic impact must be attenuated through some combination of a primary expenditure rule and an oil stabilization fund (subject to the necessary safeguards),[47] as envisaged in recent legislation in Ecuador. As a complement to such a fund, it would be worth exploring the usefulness of market-based hedging devices to cushion the uncertainty and volatility of oil prices.[48]

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[43] Specifically, the following structural measures, among others, are envisaged: comprehensive tax reform, civil service reform, and significant reduction in revenue earmarking—except where mandated by the Constitution or warranted on grounds of the benefit principle, for example, under social security programs.

[44] See evidence on the determinants of sovereign spreads in emerging markets in Kopits (2002).

[45] Both the mean and variance of yield spreads shows a slightly significant decline after the phase-in of the U.S. dollar (in the first quarter of 2000), despite the disappearance of the currency risk. In fact, since then, the spread has remained well above 1000 basis points, spiking to twice that level in mid-2002.

[46] Ecuador's Fiscal Responsibility and Transparency Law, enacted in September 2002, provides for a set of macro-fiscal rules (consisting of limits on the non-oil budget deficit, primary expenditure growth, public debt), an oil stabilization fund, and transparency requirements—broadly in line with internationally accepted good practices (as discussed in Kopits and Symansky, 1998).

[47] See, for example, the discussion of a proposed expenditure rule in Hausmann, Powell, and Rigobon (1993), and the case for adopting the Norwegian approach in Venezuela in Bjerkholt and Niculescu (2002).

[48] For a discussion of various hedging instruments used in commodity risk markets, see Davis and others (2001).

Admittedly, these implications are tentative and are subject to further testing through additional *VaR* applications, across a variety of different countries, in different circumstances. In this vein, the concluding section is devoted to an evaluation of possible limitations of the methodology and an outline of suggestions for future research.

VI. Evaluation

Overall, this experimental application of the *VaR* approach to the public sector represents a promising avenue for more realistic assessments of fiscal sustainability under uncertainty. In comparison to the conventional approach to sustainability analysis, the *VaR* analysis provides a formal and explicit quantitative framework for identifying and measuring major sources of fiscal vulnerability; in particular, it captures the effect of the volatility in underlying risk variables, as well as interactions among them. The application can be customized to any given country, incorporating specific behavioral and institutional features that characterize the country's environment.

Notwithstanding these benefits, in its present form, the *VaR* approach may be open to question on several grounds. Foremost, it can be argued that variances and covariances of risk variables estimated from past time-series data may not provide a reliable prediction of future risk. According to this view, for emerging market economies undergoing rapid structural transformation and/or suffering from major crises, application of this approach may be subject to the *Lucas critique,* which would dilute its practical usefulness for policy formulation. In the case of Ecuador, the shift to the dollar regime, as well as the turbulence that preceded the shift, could put in question the reliability of *VaR,* based on economic and financial volatilities and correlations prevailing under the previous regime.

To a considerable extent, the *VaR* is sufficiently flexible to accommodate structural changes, including regime shifts. In general, the Monte Carlo full-valuation method employed here is forward-looking and far less dependent on past data than the historical full-valuation method. Furthermore, the simulations based on this method can be complemented with expert opinion as regards future volatilities.[49] In particular, spikes and outlier observations can be smoothed or ignored on the basis of outside information. Similarly, observations for risk variables can be weighted over time. Such adjustments are not attempted herein, to preclude possible subjective judgment. Interestingly, in our test of the effect of regime shift, the ex ante and ex post simulation results for the dollarized case are surprisingly stable—though with some apparent ex ante underestimate of the decline in risk, relative to the ex post simulation—despite the scale and complexity of the crises experienced in Ecuador. This finding is supported by the observed similarity in the volatility of risk variables before and after dollarization. In any case, this issue awaits further empirical investigation in order to draw a more conclusive evaluation.

Another questionable aspect of the analysis relates to the treatment of political risk. The *VaR* may seem incomplete insofar as it excludes an explicit measure of political risk from among the

[49] For a methodology developed to model stochastic volatilities and comovements, see Engel (2000).

various risk variables. To be sure, in a real-world environment, emerging market economies often face political instability or uncertainty, especially absent a strong institutional framework. Whereas political risk deserves investigation from the perspective of fiscal vulnerability, it is in fact fully reflected in major risk variables used for the *VaR* calculations, especially in the yield spread and the exchange rate.

A potentially more serious shortcoming arises more generally from partial vulnerability assessments, that is, limited to the public sector. Indeed, such assessments should be carried out in an economy-wide context, applying a uniform and integrated *VaR* methodology simultaneously to the public sector and the financial system. In principle, an integrated risk assessment, treating the risk of systemic bank failures and government default as correlated events, is a worthwhile and feasible future endeavor.

Other possible limitations consist of the relatively free specification in the determination of some of the underlying risk variables, and of the large data and computational requirements for performing *VaR* calculations. Both of these limitations should be addressed in a future research agenda primarily by introducing methodological refinements in applications to a wide range of countries. Although the present exercise is broadly compatible with a variety of models, there is ample scope for embedding the *VaR* exercise in a fully specified macroeconomic model that includes a consistent determination of risk variables. Such an ambitious extension would facilitate tracking the consequences of policy actions on the risk-adjusted net worth of the public sector.

As regards data requirements, estimates of public sector balance sheets represent a minimum input for applying a full-fledged *VaR* analysis, particularly if conducted jointly with the financial sector in a comprehensive macroeconomic context. However, progress along these lines should be accompanied by an attempt to incorporate the volatility and comovements of risk variables in summary indicators of sustainability—possibly expanding condition (6) above. An obvious advantage in developing such indicators of fiscal sustainability under uncertainty would be the relatively modest statistical requirements. Also, summary indicators would be welcome by policy analysts and practitioners for monitoring fiscal vulnerability across a large number of emerging market economies.

Methodology and Data

This appendix outlines the computational procedure, as well as the measurement of stochastic variables and of major categories of assets and liabilities, employed to derive the risk-adjusted net worth of Ecuador's public sector. The results reported in Tables 1 and 2 are based on simulations of the future financial environment, along with the values of each asset and liability category.

Computation

The financial environment is represented by a number of correlated random variables: interest rates, inflation rate, exchange rate, equity prices, and other key economic indicators. Within the context of this environment, public sector assets and liabilities are valued (and successively revalued) to calculate equation (9). The computation entails selection of a one-year time step over which the stochastic variables are allowed to fluctuate in a correlated random process, as specified in equations (10) through (18). Actual calculations are performed with the *ValueCalc* software package developed in Barnhill (2001).

In this manner, for each run, a new financial environment (with correlated interest rate term structures, foreign exchange rate, market equity returns, oil prices, output growth, etc.) is created. This information allows the correlated values of assets and liabilities to be estimated, over a large number of calculations (approximately 10,000), in order to construct a distribution of values for each asset and liability category, and thus for the government's net worth. The resulting probability distributions can be summarized by the mean, maximum, and minimum values, standard deviation, and the *VaR* of the net worth.

This method is applied for the baseline case, allowing for movements and comovements of all stochastic variables, and for a number of alternative simulations for which selected random variables are held constant. Specifically, in simulations 1, 2, and 3 the economy is dollarized (i.e., the exchange rate is fixed.[50] In simulation 2, in addition, the home interest rate in foreign currency is fixed as well. In simulation 3, instead, the price of oil is held constant.

Each of these simulations alters the variance and the covariance of the remaining random variables, as well as the portfolio distributions for assets and liabilities. Accordingly, the mean value (of the distribution) of each asset and liability group is slightly altered as well. The resulting risk-adjusted value for each asset and liability group, as well as for the entire net worth, is calculated by setting the one-tail confidence level (say, 95 percent confidence) or conversely, the probability level (equivalent to 5 percent) of loss. An alternative way of expressing the risk-adjusted value is to derive the probability level at which net worth is zero within the specified one-year time step.

[50] For computational convenience—given the availability of all balance sheet information in U.S. dollar terms—simulation 1 provides the foundation for all simulations. Thus, for the baseline, simulation 1 is converted from dollars into sucres at the prevailing exchange rate; furthermore, the simulation is subject to the volatilities of the exchange rate, domestic inflation, and domestic interest rate, in addition to the other stochastic variables incorporated in simulation 1.

Risk variables

Altogether, seven variables, representing fundamental sources of risk, are incorporated in the calculations. The following is the list of variables measured with quarterly data series over the period 1995–99. Principal data sources are Banco Central del Ecuador (BCE), the U.S. Treasury, and the International Monetary Fund (IMF), shown in parentheses. Basic statistics of dispersion are shown in Appendix Table 1.

FX: Exchange rate of sucre per U.S. dollar (IMF).

ESR: Interest rate on Ecuador government bonds (linked to BCE base rate), in sucres (BCE)

EUDR: Spread on yield on Ecuador government bonds and on comparable U.S. government bonds, in U.S. dollars (Bloomberg)

UDR: Interest rate on U.S. government bonds, in U.S. dollars (U.S. Treasury)

ECP: Ecuador's consumer price index, seasonally adjusted (BCE)

EQ: Ecuador's non-oil GDP in constant prices, seasonally adjusted (BCE)

OP: Petroleum spot price, in U.S. dollar per barrel of West Texas Intermediate (IMF).

Balance sheet variables

The underlying data on public sector assets and liabilities for Ecuador are obtained from comprehensive balance sheet estimates for the year 2000 (expressed in U.S. dollars) in Arteta and Samaniego (2001), subject to a number of modifications. These are complemented with calculations of the residual surplus of the government (also in U.S. dollars), on the basis of data for 2000 from Ecuador's Ministry of Finance and from IMF staff estimates.

Recorded assets

All recorded assets (current, fixed, and other assets), comprising a relatively small portion of public sector assets, are measured at their book value. Foreign exchange reserves are assumed to be invested in risk-free U.S. government securities maturing in one year.

Contingent assets

For all contingent assets (petroleum reserves, biodiversity, carbon dioxide capture, and profits from state-owned enterprises), the present value is computed from the expected annual flow generated over an appropriate time horizon. The yearly discount rate is gradually reduced from 12.5 percent in 2001 to 9 percent beyond 2004.

Appendix Table 1. Ecuador: Volatility and Correlation of Risk Variables, 1995:1–1999:4
(In percent rate of change)

Variable	Standard Deviation	Correlation Matrix						
		UDR	EUDR	ESR	FX	ECP	EQ	OP
UDR	0.01	1.00	0.37	0.06	0.47	0.04	-0.24	0.36
EUDR	0.08		1.00	0.27	0.59	0.26	-0.35	0.16
ESR	0.11			1.00	0.44	0.19	-0.37	-0.25
FX	0.19				1.00	0.47	-0.49	0.27
ECP	0.07					1.00	-0.06	0.37
EQ	0.04						1.00	-0.19
OP	0.24							1.00

Petroleum reserves dominate balance sheet in terms of both magnitude and volatility. The stock of reserves of state-owned Petroecuador (approximately 5.8 billion barrels), plus the government's share in privately owned reserves, are estimated at US$76 billion or about four times the value of trend GDP. The volume of future oil production is assumed to be known with certainty and new reserves from the potential future discovery are not valued. Specifically, the reserves are projected to generate a net revenue flow over the forthcoming 27-year period, rising in the initial years and leveling off after 2004. The net present value of this revenue flow, calculated according to equations (15) and (16), amounts to less than one half of the value of the stock of reserves.

Ecuador is well endowed with a variety of biodiverse resources in 24 conservation areas (12 million hectares). Protection of these resources is expected to yield revenue from various sources (including from future pharmaceutical applications). In addition, under the Kyoto Protocol, Ecuador is expected to benefit from the sale of carbon dioxide emission rights (given its forest resources) to industrial countries that are not able to meet the targeted reduction in emission. The present value of the projected annuities from biodiversity and carbon dioxide capture is calculated over a 100-year period.

Estimates of the market value of state-owned enterprises are used as the basis for applying equation (14) for revaluing enterprises in the electricity and communication sectors. No estimates are available for enterprises in the mining sector.

Recorded liabilities

The stock of domestic and external financial liabilities is measured at their outstanding value, nearly equivalent to GDP. Short-term liabilities and 30 percent of domestic liabilities are assumed to mature in one year. The remaining 20 percent and 50 percent of domestic liabilities are assumed to mature in 6 and 15 years, respectively. External liabilities are assumed to be entirely denominated in U.S. dollars; 70 percent are amortized over 20 years and 30 percent over 7 years. Other liabilities, mainly in the form of outstanding obligations to depositors, arising from prior bank rescue operations, are projected to be amortized over 3 years.

Contingent liabilities

There are three major types of contingent liabilities—natural disasters, banking crises, and aging—held by the government in Ecuador, the sum of which is close to the value of GDP. As on the asset side, their present value is calculated with a discount rate gradually declining from 12.5 percent in 2001 to 9 percent in 2004 and thereafter.

Ecuador is vulnerable to a range of potential natural disasters, including volcanic eruptions and earthquakes. However, the *El Niño* weather phenomenon is the only contingency for which estimates are available. The potential cost of the *El Niño* is calculated from a weighted average of "severe" and "less severe" scenarios. Whereas for the severe scenario the cost is estimated as an annuity over a 20-year period, for the less severe occurrence it is valued as an annuity over 3 years, with weights of 35 percent and 65 percent, respectively.

On the basis of recent experience with banking crises in Ecuador, the contingent liability associated with a deposit guarantee scheme is calculated with a constant annuity extended over a 20-year period.

The Social Security Institute of Ecuador (IESS) is facing a significant financial imbalance, its operations are currently under review by a Commission of Intervention, and Congress is considering a major reform of the system. An estimate of net unfunded liabilities of the public pension program (i.e., future flow of pension benefits accrued, less contributions) accumulated over the next 25 years is available for a baseline (no reform) scenario.

Residual primary balance

The present value of the residual primary balance of the general government (valued as a perpetuity) is based on the difference between the projected levels of government revenue, less public pension contributions, oil revenue, interest income, and operating surplus of state-owned enterprises; and of government expenditure, less public pension benefits and interest payments. Projections of residual revenue and residual expenditure are based on the assumption of unitary elasticity of these flows with respect to non-oil output.

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