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Assessing Debt Sustainability in Emerging Market Economies Using Stochastic Simulation Methods

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Abstract

This paper applies stochastic simulation methods to assess debt sustainability in emerging market economies and provide probability measures for projections of the external and public debt burden over the medium term. The vulnerability of public debt to adverse shocks is determined by a number of interrelated factors, including the volatility of output, financial fragility, the endogenous response of the risk premium, and sudden stops in private capital flows. The vulnerability of external debt is sensitive to the determination of the exchange rate and to the pricing of traded goods. We show that fiscal policy can act in a preemptive manner to prevent the debt burden from rising significantly over the medium term. This requires flexibility in fiscal planning, which many emerging market economies lack. Emerging market economies therefore face a difficult trade-off between managing the risk of a debt crisis and pursuing other important fiscal policy objectives.

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I. INTRODUCTION

Debt sustainability has played an increasingly important role in the analysis of macroeconomic policies in low- and middle-income countries. Debt sustainability assessments (DSAs) have become a standard element of IMF Article IV and program reviews. They play an integral role in Paris Club negotiations on debt rescheduling and figure prominently in determining the grant versus loan components of IDA14 allocations to low-income countries.

The standard DSA framework used by the IMF and the World Bank basically entails conducting stress tests with reference to a baseline projection scenario.[2] The baseline is intended to establish the most likely outcome conditional on underlying policies. Alternative projection scenarios include a set of standard adverse shocks, which typically include a transitory decrease in output growth, an increase in interest rates, and a depreciation of the exchange rate, along with other shocks that are selected on a case-by-case basis. The stress tests have some important advantages, along with a few shortcomings. The DSA framework largely consists of accounting identities, with few economic (behavioral) relationships, and hence, the projections are generated by an underlying economic structure. Standardization of the shocks facilitates comparisons across countries and over time. The stress tests are therefore relatively straightforward to interpret from a technical perspective. However, they are difficult to interpret from an economic perspective. The accounting identities do not take into account interaction among economic variables. For instance, an interest rate shock has no effect on output or the exchange rate. Moreover, it is difficult to assess the likelihood of the alternative scenarios.

Recent studies (notably by Barnhill and Kopits, 2003; Garcia and Rigobon, 2004; and Mendoza and Oviedo, 2003) have applied stochastic simulation methods to develop a DSA framework that generates probability measures that take into account interactions among key economic variables. Our analysis includes a number of features that have not been examined in these studies. In particular, monetary and fiscal policy are set with reference to well-defined objectives, implemented using forward-looking policy rules. Moreover, debt management plays a central role in our analysis. External and public debt have explicit maturity structures, and we include a distinction between debt denominated in foreign versus domestic currency. Our model also allows for local- versus producer-pricing of traded goods, which has important implications for assessing the sustainability of external debt.

Our paper is also motivated by the "debt intolerance" question posed by Reinhart, Rogoff, and Savastano (2003). They point out that debt defaults have often occurred in emerging market economies with moderate debt levels and ask why emerging market economies have defaulted so often compared to advanced economies with comparable or even higher debt

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[2] This is documented in IMF (2002 and 2003). A similar framework has been adopted by the IMF and World Bank (2004a and 2004b) to assess debt sustainability in low-income countries.

burdens. What factors make emerging market economies more vulnerable to adverse shocks? Our stochastic simulation experiments are designed to provide some insight into these questions, drawing on several factors that have been proposed in the recent literature.[3]

We specify a stochastic simulation model that encompasses four key factors: macroeconomic volatility, financial fragility (reliance on short-term, foreign currency borrowing), the endogenous response of the risk premium, and "sudden stops" in private capital flows. Stochastic simulation methods are used to examine how the factors interact to influence the amount of uncertainty surrounding external and public debt over the medium term. Our simulation results indicate that the factors listed above taken together make public debt in emerging market economies much more vulnerable to adverse shocks. The vulnerability of external debt is found to be sensitive to two model specification issues, namely, the determination of the exchange rate and the pricing of traded goods. We examine the role of fiscal policy in managing default risk. Our simulation results demonstrate how fiscal policy can act in a preemptive manner to prevent the public debt burden from rising significantly over the medium term. However, this requires flexibility in fiscal planning, which many emerging market economies lack. We believe that this is an important aspect of the debt intolerance question posed by Reinhart, Rogoff, and Savastano (2003).

The next section of the paper reviews the literature on debt sustainability, highlighting some of the key factors that have been proposed to explain why emerging market economies are vulnerable to adverse shocks. Section III provides a brief overview of the basic structure of the stochastic simulation model and the methodology used to calibrate the parameters. Section IV presents the stochastic simulation results. The final section concludes by summarizing the main findings and commenting on areas for further research.

II. Literature Review

A. Debt Sustainability Assessments

The DSA framework outlined in IMF (2002 and 2003) reports stress tests based on adverse shocks taken separately and simultaneously. The distinction between an isolated shock and several simultaneous shocks is quite important. If shocks to output, interest rates, and the exchange rate are independent, the joint likelihood of large adverse shocks would be relatively low, which would make the scenario "improbable." However, IMF (2003, p. 16) argues that adverse movements in output, interest rates and the exchange rate have tended to precede financial crises in emerging market economies. More generally, output, interest rates, the exchange rate, and debt are believed to be jointly determined. Determining the joint likelihood of large adverse movements in these variables is essential for assessing debt sustainability.

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[3] This paper focuses on debt sustainability in emerging market economies, which refers to middle-income countries that access external private capital markets on a regular basis. IMF (2004) examines debt sustainability in low-income countries; Sun (2004) examines debt sustainability in Heavily Indebted Poor Countries (HIPC).

A number of studies have applied stochastic simulation methods to quantify the joint probability aspect of DSAs. The basic methodology entails applying Monte Carlo simulation methods to a macroeconomic model that captures interactions among key variables (including output, interest rates, the exchange rate, and debt). The simulations generate empirical probability distributions for each of the variables, which enables one to gauge the likelihood of a given outcome. In particular, stochastic simulation methods can provide a measure of the risk that the debt burden rises significantly over the medium term, a key issue in assessing debt sustainability.

Different approaches have been taken to model the interactions among economic variables in stochastic simulation studies. Barnhill and Kopits (2003) apply the value-at-risk methodology to assess fiscal sustainability in a framework that takes into account covariances between risk variables. Garcia and Rigobon (2004) examine stochastic simulation experiments using a vector autoregression that captures correlation between macro variables. Mendoza and Oviedo (2003) apply stochastic simulation methods in a dynamic general equilibrium modeling framework where comovement between macro variables is determined by an explicit theoretical structure. In a normative vein, Tanner and Carey (2005) discuss potential fiscal objective functions that might apply in a stochastic macroeconomic. Their value-at-risk objective function summarizes the maximum fiscal adjustment that a country is willing to incur in order to prevent further increases in debt – precisely the undesirable outcomes revealed by such stochastic simulations. Our analysis includes a number of features that have not been examined in these studies, including forward-looking monetary and fiscal policy rules, an explicit maturity structure and currency denomination for external and public debt, and a distinction between local- versus producer-pricing of traded goods. In addition, our analysis encompasses a number of key factors in a common framework to investigate how their interaction influences debt sustainability.

B. Factors Influencing Debt Sustainability

The series of financial crises in emerging market economies over the past decade has led to vast empirical and theoretical literature. Financial crises differ greatly in their causes and consequences. Empirical studies have shown that it is difficult to predict debt distress episodes with a reasonable amount of confidence. Nevertheless some common elements have emerged in this literature to help explain why emerging market economies are vulnerable to adverse shocks. This review highlights some of the key factors influencing debt sustainability, namely: macroeconomic volatility, financial fragility, endogenous risk premium, and sudden stops in capital flows.

Macroeconomic volatility

Macroeconomic volatility has often played a prominent role in debt distress episodes. Empirical studies by Catão and Sutton (2002) and Catão and Kapur (2004) indicate that countries with more volatile output and terms of trade and destabilizing macro policies are more likely to default on their sovereign debt. The terms of trade and output are much more volatile in emerging market economies than in advanced economies. Our calculations indicate that the standard deviation of the terms of trade and output in emerging market economies is roughly double that observed in the major advanced (Group of Seven, G-7) economies.[4] Catão and Kapur (2004) argue that macroeconomic volatility is a key determinant of default risk and can help explain the debt intolerance question posed by Reinhart, Rogoff and Savastano.

Financial fragility

Financial fragility attracted a great deal of attention in the wake of the Asian crisis in 1997-98. Large exchange rate exposures in banking and corporate sectors made many of the Asian economies vulnerable to a large exchange rate devaluation (Chang and Velasco, 1998; Radelet and Sachs, 1998; and Hawkins and Turner, 2000). The predominance of short-term, foreign-currency-denominated borrowing was a major factor underlying the liquidity crises. Emerging market economies are, to a great extent, unable to borrow at long maturities in domestic currency (the so-called original sin hypothesis)[5] and hence, must resort to issuing short-term, foreign-currency-denominated debt (Hausmann, 2004). Abrupt movements in interest rates and exchange rates therefore can have a major impact on the debt service burden, making these economies vulnerable to a debt crisis.

Endogenous risk premium

Interaction between the expectations of debtors and creditors plays a critical role in assessing default risk, particularly for emerging market economies that are financially fragile. Sudden swings in investor sentiment can lead to an abrupt widening of yield spreads along with a large depreciation of the exchange rate, which can significantly raise debt service costs and the debt burden (measured in domestic currency). The higher debt burden in turn raises the risk of debt default. Thus, the simultaneous interaction between creditors' assessment of default risk, large movements in interest rates and the exchange rate, and the debt burden can greatly amplify the nonlinear aspect of debt dynamics. The endogenous response of the risk premium to changes in default risk therefore plays an important role in assessing debt sustainability.

Several recent studies have examined the interaction between default risk, an endogenous risk premium, and debt sustainability. Akemann and Kanczuk (2005) construct a model in which higher interest rates increase debt service costs, which worsens the fiscal outlook.

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[4] The terms of trade in emerging market economies has a standard deviation of about 20% on average over the period 1971–2004, versus 9% in the G-7 economies. GDP growth has a standard deviation of about 4.2% in emerging market economies, versus 2.2% for the major advanced economies. Unless stated otherwise, all calculations reported in this paper are based on a sample of 31 emerging market economies, which roughly corresponds to the economies included in the Institute of International Finance (IIF) analysis of capital flows to emerging market economies.

[5] There are a few notable exceptions recently. In October 2004, Uruguay issued the equivalent of about US$280 million in local currency (peso)-denominated (2-year) bonds. In November 2004, Columbia issued the equivalent of US$380 million in local currency (peso)-denominated (5.5-year) bonds. More recently, in September 2005, Brazil issued the equivalent of US$1.5 billion in real-denominated (10-year) bonds.

Their model imposes a fiscal constraint on adjustment of the primary surplus, which makes the government "unable to repay" its debt obligations. Adverse shocks raise the probability that the fiscal constraint might bind at some point in the future. This raises the risk of debt default, which gets reflected in the risk premium. Dailami, Masson, and Padou (2005) examine how changes in global (U.S.) interest rates can affect default risk on emerging market bonds, which gets reflected in emerging market bond spreads. They stress that the relationship between global interest rates and default risk is nonlinear and depends on the external debt burden. Arellano (2005) analyzes the government's default decision based on explicit costs and benefits in the context of a stochastic general equilibrium open economy model that includes an endogenous default premium determined in a model-consistent manner. When the debt service burden exceeds a "threshold" level in the model, the government assesses that the costs of meeting its debt obligations outweigh the benefits. Blanchard (2004) constructs a model in which the risk premium and the exchange rate evolve endogenously with the probability of default. An increase in the real interest rate beyond some threshold level in the model increases default risk to the point where the *risk-adjusted* rate of return on public debt declines. This makes the government unable to compensate investors for the higher default risk and hence prevents the government from issuing new debt or refinancing maturing debt.

"Sudden stops" in capital flows

Several studies have stressed that when the risk premium on external debt exceeds some threshold level, foreign investors become unwilling to lend and issuers become unwilling to borrow. Pescatori and Sy (2004) argue that market participants often view sovereign bond spreads above 1,000 basis points as signaling significant probability of default, making it very difficult to access external credit. They present empirical evidence showing that emerging market economies experience severe financing difficulties when their bond spreads exceed 1,000 basis points.

Several studies have emphasized that emerging market economies are prone to "sudden stops" in private capital inflows, which result in a loss of foreign reserves along with a sizable real exchange depreciation required to improve the current account (notably Calvo, 1998; and Krugman, 1999). Arellano and Mendoza (2002) characterize "sudden stop" episodes with reference to a set of empirical regularities which include a sudden loss of access to international capital markets; a large improvement in the current account deficit; a collapse of domestic production and aggregate demand; sharp corrections in asset prices and in the prices of nontraded goods relative to traded goods; and sharp declines in credit to the private sector.

Abrupt current account adjustments, often accompanied by sudden stops in capital flows, have played a prominent role in most of the major financial crises over the past decade.[6] Sudden stops have often been highly disruptive, forcing costly adjustment and in some cases

[6] Edwards (2004) points out that there have been large current account reversals without sudden stops in capital flows and vice versa, indicating that some countries have been able to draw down foreign reserves to prevent abrupt adjustments in the current account.

leading to episodes of debt distress. Calculations reported by Calvo (2003) indicate that the capital account to GDP ratio declined by 11 percentage points on average in 15 financial crises that occurred over the period 1981–97 (Table 1, p. 3).[7] In many cases, episodes of sudden stops and abrupt current account reversals were accompanied by currency crises, involving large exchange rate devaluations along with large reductions of foreign reserves.[8] We abstract from foreign reserve management in our analysis and hence treat sudden stops in capital flows and abrupt current account adjustment as being synonymous. A number of empirical studies have examined the adjustment costs caused by sharp reversals in current account balances, but the results are mixed.[9]

A number of theoretical models have been developed to explain the sudden stop phenomenon.[10] Calvo (2003) constructs a model in which the government's capacity to raise tax revenues is limited by the distortionary effect of taxes on growth. This creates a threshold level for tax rates, which constrains the ability of the government to respond to adverse shocks. The debt solvency condition is violated when the revenue financing constraint binds. Arellano and Mendoza (2002) and Mendoza (2005) incorporate financial-frictions channels into a small open economy equilibrium business cycle model. They show that occasionally binding borrowing constraints can yield infrequent sudden stops in capital flows, large reversals in the current account, and deep recessions.

To sum up, several factors have been proposed in the literature to explain the vulnerability of emerging market economies to adverse shocks. Macroeconomic policy has played an important role as a destabilizing force, as have volatile output and terms of trade shocks. Financial fragility is also believed to play a key role: short-term, foreign-currency borrowing makes emerging market economies vulnerable to large movements in interest rates and exchange rates. The endogenous response of the risk premium to adverse shocks and the possibility of sudden stops in capital flows accentuate the nonlinear aspect of debt dynamics.

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[7] Similarly, calculations reported by Hostland and Schembri (2005) indicate that the current account to GDP ratio improved by about 10 percentage points on average in the year following 11 major financial crises that occurred over the period 1995-2001.

[8] Calvo, Izquierdo, and Mejía (2004) found that 63% of the large exchange rate depreciations in their sample of emerging market economies were associated with sudden stop episodes. Statistical analysis by Edwards (2004) indicates that countries subject to large current account reversals have a significant probability of a major devaluation.

[9] Milesi-Ferretti and Razin (1998), Debelle and Galati (2005), and Croke, Kamin, and Leduc (2005) conclude that sharp reversals are not systematically related to slowdowns in growth, whereas Freund and Warnock (2005) found large significant effects. Edwards (2004), Calvo, Izquierdo, and Mejía (2004), and Frankel and Cavallo (2004) show that the adjustment costs are lower in more open economies (measured by exports plus imports relative to GDP).

[10] See Arellano and Mendoza (2002) for a more extensive survey of the literature on sudden stops.

It is important to recognize that the factors outlined above are interrelated. Our stochastic simulation model is designed to nest these factors in a common framework so that we can examine how they interact to influence debt sustainability.

C. Recent Trends

Much of the existing literature on debt sustainability has focused on external debt. This is mainly because there hasn't been an active market for domestic debt in most emerging market economies until recently and also because data on domestic debt are not readily available in most countries. Various indicators suggest that most emerging market economies have become less vulnerable to an external debt crisis since the Asian crisis in 1997–98 and the Russian crisis in 1998. There have been numerous credit rating upgrades over the past few years; emerging market bond spreads have declined to record lows. The major improvement in assessments of creditworthiness reflects a combination of factors, including favorable external conditions (low global interest rates in particular), improvements in macroeconomic policies in most emerging market economies, and progress on structural reforms in some countries.

The average external debt burden in middle-income countries has declined from 44% of GNI in 1999 to 38% in 2003, but remains well above the average level of 33.7% over the period 1982–98 (Table 1).[11] At the same time, emerging market economies have become much more open—exports in middle-income countries have increased from 31.6% of GNI in 1999 to 39% in 2003, well above the average level of 22% over the period 1982–98. There has also been a major swing in the current account from a balanced position in 1999 to a surplus equal to 1.5% of GDP in 2003, well above an average deficit at 1.2% of GDP over the period 1982–98. In addition, foreign reserves have increased from 31% of GNI in 1999 to 52% in 2003, well above the average level of 20.5% of GDP over the period 1982-98. Taken together, the developments outlined above make emerging market economies much better placed to weather adverse shocks to external debt.

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[11] The external debt burden averaged across *all developing countries* (low- and middle-income countries combined) declined from 45% of GNI in 1999 to 35% in 2004 (World Bank, 2005, p. 2).

Table 1. Balance of Payment Indicators for Middle-Income Countries

Percent	*Average 1982-98*	*1999*	*2000*	*2001*	*2002*	*2003*
External debt / GNI	33.7	44.0	39.0	39.0	39.0	38.0
Exports / GNI	22.1	31.6	34.7	34.0	36.2	38.8
Trade balance / GNI	-1.3	-0.1	0.6	0.0	0.9	1.3
Current account balance / GNI	-1.2	0.0	0.7	0.2	1.1	1.5
External debt / Exports of goods and services	156.1	139.0	113.0	114.0	108.0	99.0
Reserves / External debt	20.5	31.0	33.0	37.0	44.0	52.0

Source: World Bank Debtor Reporting System (DRS) database.

There is, however, a concern that public debt burdens have risen in some emerging market economies over the past few years, spurred by the development of domestic debt markets (World Bank, 2005, pp. 76-80). Our calculations indicate that the public debt burden in 31 emerging market economies increased from an average level of 53.6% of GDP in 2000 to 58.6% in 2003, before declining slightly to 55.8% in 2004.[12] Moreover, in 12 of the 31 countries in our sample, public debt burdens increased over the period 2002-04, despite the favorable external conditions. In 2004, public debt burdens exceeded 80% of GDP in 5 of the 31 countries. We will explore how the increase in public debt burdens in some emerging market economies has affected their vulnerability to adverse shocks.

III. Overview of Stochastic Simulation Model

This section of the paper highlights some of the key features of the model that play an important role in the results.[13] The macroeconomic core model consists of a few reduced-form equations for aggregate demand and supply dynamics and the inflation process. Ideally, we would prefer to have an underlying structure with more explicit microfoundations. Our preference for a small, aggregate model is largely determined by computational requirements of stochastic simulation methods. In addition, the reduced-form specification greatly facilitates calibration of the parameters. The model presented in this paper should be interpreted as an early stage of a broader research agenda that aims to develop stochastic simulation models based on more explicit structural interpretations. We will return to this issue at the end of the paper.

Most stochastic simulation models are calibrated with reference to historical data. IMF (2003, p. 21) argues that this can be a major drawback because of "the lack of sufficient data or stable time series for many countries." We address this concern by adopting a calibration methodology that is less susceptible to poor data quality. Rather than relying on estimates specific to a particular country, our model is calibrated to match broad, stylized facts that are

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[12] These calculations are based on data compiled for IMF (2005).

[13] For a more detailed discussion of the stochastic simulation model and the calibration methodology, see Hostland and Karam (2005).

common across a large set of emerging market economies.[14] In addition, we impose our priors on certain aspects of the model to address some of the problems caused by unstable time series properties of the data. For instance, monetary policy in our model is set using an inflation targeting rule, which does not correspond with how monetary policy was set in most economies over most of the historical period. The time series properties of inflation generated by our model are therefore significantly different from those observed over the historical period (particularly in those emerging market economies that have experienced episodes of hyperinflation), as they are calibrated to be consistent with an inflation targeting environment. As a consequence, our stochastic simulation results should be interpreted as being conditional on a credible inflation targeting regime.

Some equations in the model are specified on theoretical grounds. For example, the exchange rate is determined by the uncovered interest parity condition, and the term structure of interest rates is modeled using the expectations hypothesis. In both cases, expectations are formed by combining backward- and forward-looking components, so as to encompass purely adaptive and fully rational (model-consistent) expectations as two extremes. Other parameters in the model are calibrated to match selected moments of the data. This entails setting parameters such that the variances and autocorrelation coefficients simulated by the model correspond as close as possible to those observed in the data. For instance, in the case of uncovered interest parity condition, the forward- and backward-looking components of expected exchange rate changes are combined such that the variance and autocorrelation of exchange rate changes simulated by the model match those in the data.

Some parameters are calibrated in a more subjective manner. In the case of inflation, the monetary policy authority in the model aims to keep inflation within a target range using a forward-looking reaction function. This entails setting its instrument—the short-term nominal interest rate—each quarter so as to bring inflation back to the target level over the coming year or two (depending on the nature of the shock). The parameters are calibrated to be consistent with the low and stable inflation environment that emerged in the early 1990s in most advanced countries. The model generates fluctuations in inflation that are substantially smaller than those observed in the data prior to the 1990s, especially in the case of those emerging market economies that experienced episodes of hyperinflation. This has implications for all nominal variables in the model (such as nominal output, interest rates, and the exchange rate).

It is important to recognize that the objective of our analysis is not to explain the data over the historical period, but rather to assess the risks going forward, conditional on explicit policies. For the purposes of this paper, we gauge the risks facing a "generic" emerging market economy conditional on monetary and fiscal policy rules that are designed to attain well-defined objectives. The monetary authority's objective is defined with reference to an inflation target; the fiscal authority's objective is defined with reference to a debt target. The

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[14] For a more detailed discussion of estimation versus calibration approaches to specifying macro models, see Berg, Karam, and Laxton (2005) and the references therein.

stochastic simulation results therefore must be interpreted as conditional on credible monetary and fiscal policy regimes.

The fiscal authority in the model seeks to prevent the public debt burden from rising significantly over the medium term. This is implemented using an endogenous reaction function. The fiscal authority responds to adverse shocks by reducing discretionary spending to ensure that the projected public debt burden reverts to its initial level over the medium term. There is feedback between the fiscal policy measures undertaken and aggregate demand. Aggregate demand shocks impinge on the primary fiscal balance and on debt service costs. The fiscal policy response to unanticipated fiscal developments in turn affects aggregate demand. The interaction between policy changes and economic developments are solved simultaneously using model-consistent expectations. Later in the paper we examine the implications of alternative fiscal policy rules.

External debt also plays a prominent role in the model. The trade sector includes price and volume equations. In the benchmark specification of the model, 90% of exports and imports are priced in foreign currency; the remaining 10% are priced in domestic currency.[15] This trade pricing assumption has a major influence on some of our results. The model also includes valuation effects on debt stocks. All external debt is denominated in foreign currency, whereas only half of public debt is denominated in foreign currency.[16] External debt is therefore more vulnerable to a large exchange rate depreciation. The maturity structure of debt also plays an important role in our analysis. Public debt has a much shorter average term to maturity than external debt, making public debt service more susceptible to large increases in interest rates. These differences in debt management have an impact on the vulnerability of public and external debt to adverse interest rate and exchange rate shocks.

A. Modeling Default Risk

We do not include episodes of debt default in our stochastic simulation framework because it would require specifying a rule for writing down the value of debt. In principal, the size of the write-down should be determined with reference to the "sustainable" level of debt. It is not clear how to define "debt sustainability" in a probabilistic framework. We leave this for future research.

The debt solvency condition is not violated in the simulations presented in this paper. The trade balance in our model adjusts to ensure that the present discounted value of future trade balances exceeds the value of external debt. Similarly, the fiscal authority is able to adjust

[15] This is supported by empirical evidence documented by Hostland and Schembri (2005).

[16] The model is calibrated such that 38% of public debt is issued externally (denominated in foreign currency), while another 12% is issued domestically (denominated in local currency), but indexed to the exchange rate. IMF (2005, p. 17) estimates that the proportion of public debt denominated in foreign currency domestic has declined from 55% at end-2002 to under half at end-2005.

discretionary spending to ensure that the solvency condition for public debt is satisfied. This assumes that the government has sufficient room to make changes in discretionary spending without having to raise taxes or cut nondiscretionary spending. We also abstract from longer-term growth implications of raising distortionary taxes (Calvo, Izquierdo, and Talvi, 2003; and Calvo, 2003) or cutting public infrastructure spending. Instead of setting an explicit fiscal constraint (as in Mendoza and Oviedo, 2003; and Hausmann, 2004), we generate probability distributions for the primary fiscal balance to gauge the amount of fiscal effort required to keep the public debt burden from rising significantly.

Investors in the model gauge the risk of default with reference to the debt burden projected over the coming year using model-consistent expectations. When the debt burden rises above the initial level, investors demand a higher risk premium to compensate for the higher probability of debt default at some point in the future. The fiscal plan is credible in the sense that the model-consistent expectations can be derived under the fiscal policy rule. However, investors are uncertain about whether the fiscal authority might become *unable* or *unwilling* to repay in the event of subsequent adverse shocks. The increase in default risk also leads to an exchange rate depreciation (along the lines of Blanchard, 2004). This has two opposing effects. The valuation effect refers to the higher value of the debt that is denominated in foreign currency, which raises debt service payments. This is more than offset by the improvement in the trade balance. On balance, the exchange rate response stabilizes the external sector and thereby limits the amount of volatility in the current account and the external debt burden. The magnitude of the exchange rate response is calibrated such that the amount of volatility generated by the model matches that observed in the data.[17]

We also incorporate sudden stops in capital flows into the model. This is implemented by imposing a ceiling on the risk premium. The ceiling is set at a level (800 basis points) where the sudden stop constraint binds occasionally.[18] When this constraint binds, the exchange rate depreciates discretely which leads to a rapid improvement in the current account and a sharp decline in capital flows.[19] The endogenous risk premium and sudden stop in capital flows reinforce one another, accentuating the nonlinearity in debt dynamics.

[17] The exchange rate response is calibrated such that there is a 10% probability that the external debt burden generated by the model will increase by 9.5 percentage points over a five-year period, which is equal to the average outcome for the G-7 countries over the period 1975-2003 calculated using the data on net international investment positions compiled by Lane and Milesi-Ferretti (2005).

[18] The unconditional probability of a sudden stop is between 4% and 7% in the simulations reported in the paper. This range matches the incidence of sudden stops calculated by Edwards (2004, Table 19) for the following regions: Asia (3.9%), Latin America and Caribbean (4.5%), Africa (6.9%), and Eastern Europe (7.1%).

[19] Our analysis abstracts from the use of foreign reserves and official financing in the event of a sudden stop in capital flows.

IV. Stochastic Simulation Results

The stochastic simulation framework nests a number of features that make emerging market economies vulnerable to adverse shocks. We present simulation results with reference to a "benchmark" specification of the model that is calibrated to match empirical regularities observed in advanced countries. We then sequentially add features to the model to show how each in turn influences debt sustainability.

A. Benchmark Specification for Advanced Countries

To simplify our analysis we begin by setting the implicit interest rate of debt (r) equal to the economic growth rate (g) in the benchmark specification. This results in a steady state growth rate equilibrium where the trade balance and primary fiscal balance are both zero. The advanced country does not pay a risk premium on external or public debt. All of external and public debt is denominated in domestic currency. Each of these assumptions will be relaxed later when we examine simulations for emerging market economies.

The external debt burden is set to an initial level at 32% of GDP.[20] Trade is initially balanced; debt service payments amount to 1.6% of GDP, implying a current account deficit at the same level. The public debt burden is initially set at 55% of GDP.[21] The overall government budget is initially in balance; debt service payments amount to 2.7% of GDP, equal to the primary fiscal deficit. The initial conditions characterize the stock-flow steady-state equilibrium of the fiscal and external sectors of the model in the absence of stochastic shocks.

Stochastic simulations involve the following sequence of events. At the beginning of each quarter, the monetary and fiscal authorities in the model set their policy instruments. Stochastic shocks then arrive and displace all endogenous variables. The monetary and fiscal authorities revise their policy setting in the following quarter, taking into account the unanticipated developments resulting from the stochastic shocks. The simulations continue over a five-year time horizon, which corresponds to the IMF DSA framework (IMF 2002 and 2003). The five-year stochastic simulation runs are repeated 10,000 times, resulting in 50,000 annual simulation values for each endogenous variable. This enables us to generate probability distributions with fairly good precision.

The model and shocks are symmetric and hence probability distributions for all simulated variables are centered on their respective mean (steady-state) values. This is illustrated in Figures 1 and 2, which show 80% confidence intervals for four variables of interest: the trade balance, external debt, the primary fiscal balance, and public debt, each measured as a

[20] This is estimated to be the average level for middle-income countries in 2004, based on World Bank DRS data.

[21] This is the average level for 31 emerging market economies in 2004, based on data compiled for IMF (2005).

percent of GDP. The confidence interval for the ratio of external debt to GDP widens over a five-year projection horizon, such that 80% of the outcomes in the fifth year fall within the 22.6% to 41.4% range, centered on the steady-state level of 32%. This implies that there is a 90% probability that external debt will remain below 41.4% of GDP in the fifth year, or equivalently there is a 10% risk that external debt will exceed 41.4% of GDP in the fifth year. The confidence interval for trade balance as a percent of GDP also widens over the projection horizon, with 80% of outcomes in the fifth year within the -3.3% to 3.3% range.

The 80% confidence interval for the ratio of public debt to GDP widens to 6.7 percentage points in the fifth year, which is substantially narrower than that for external debt to GDP (18.9 percentage points). There is a 10% risk that public debt will exceed 58.3% of GDP in the fifth year, starting from an initial level of 55%. Similarly, the confidence interval for the primary fiscal balance widens to 2.2 percentage points in the fifth year, significantly less than that for the trade balance (6.7 percentage points). Thus, in the benchmark specification of the model there is more variability in the external debt burden and the trade balance than in the public debt burden and the primary fiscal balance.

The amount of variability in the public debt burden and the primary fiscal balance is largely determined by the fiscal policy rule. The fiscal authority in the model aims to bring the public debt level back to target level (55% of GDP) over the long term. The control feedback mechanism contains the range of outcomes for public debt burden, at the expense of raising the amount of variability in the primary fiscal balance. The exchange rate plays a similar role in the external sector (discussed above). The role of the fiscal policy rule and the exchange rate are discussed in more detail later in the paper.

The stochastic simulation experiments generate probability distributions for all endogenous variables in the model. Hence, there is a multitude of economic outcomes that could be examined. For the purposes of this paper, we focus on probability that the external and public debt burdens increase significantly over the five-year projection horizon. This is summarized using 90% confidence levels in the fifth year of the projection. We also examine the amount of fiscal effort required to keep the public debt burden from rising over the medium term. This is measured using the 90% confidence level for the primary fiscal balance as a percent of GDP. Similarly, we examine the amount of external adjustment required to keep the external debt burden from rising using the 90% confidence level for the trade balance as a percent of GDP.

Figure 1. Confidence Intervals for Trade Balance and Primary Fiscal Balance

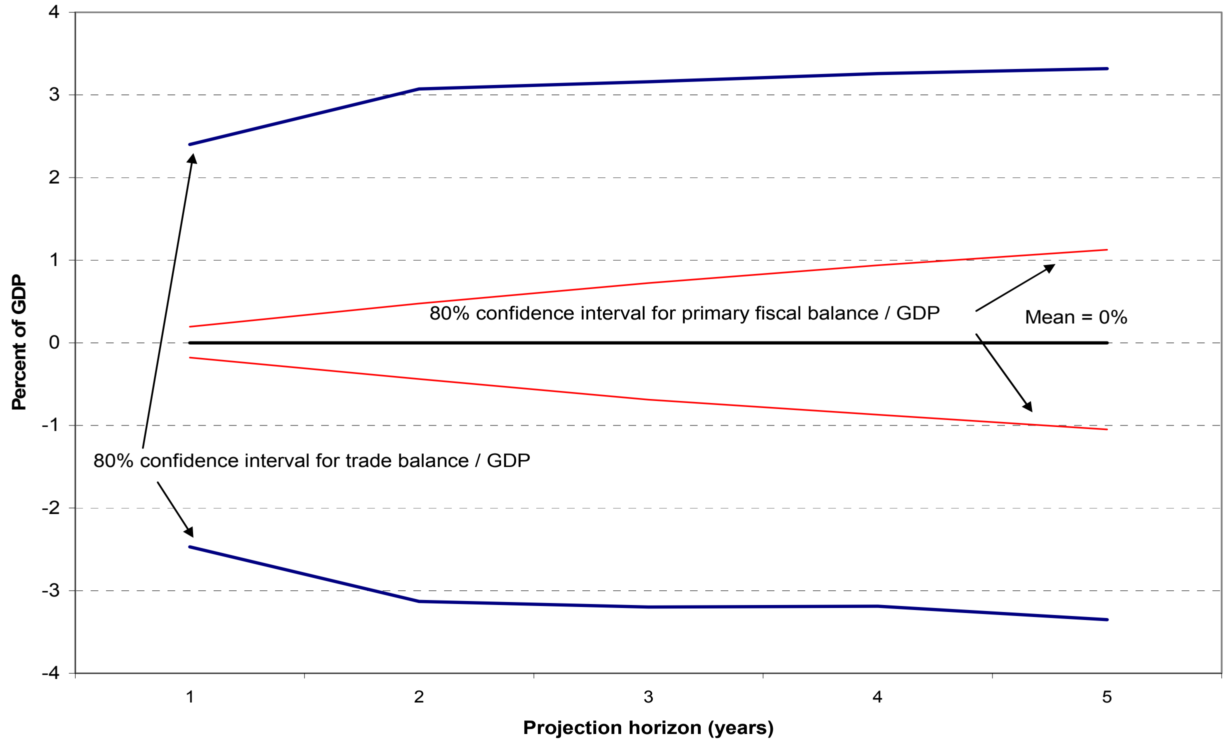
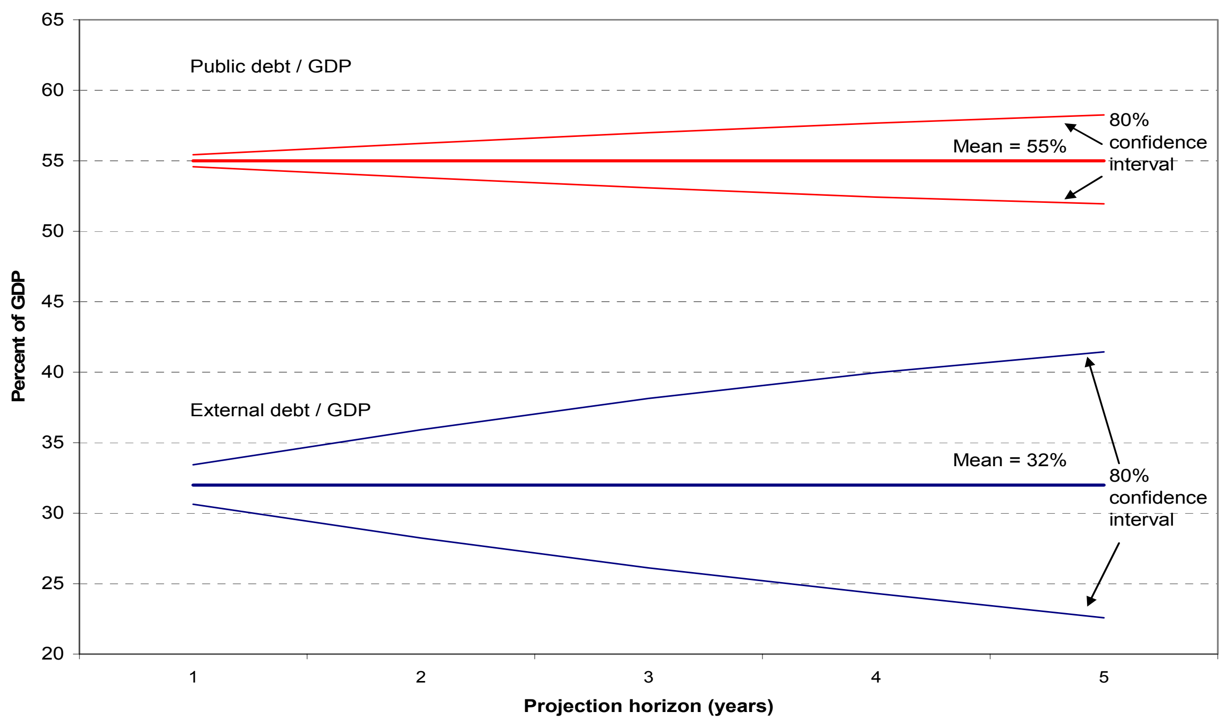


Figure 2. Confidence Intervals for Public and External Debt



B. Extensions to Emerging Market Economies

We now add a number of features to the benchmark "advanced country" specification of the model to provide insights into why emerging market economies are more vulnerable to adverse shocks. First, the model is recalibrated to generate a higher amount of volatility in output. We then sequentially add foreign-currency-denominated debt, an endogenous risk premium, and sudden stops in capital flows.

Output volatility
A number of studies that have stressed that output growth has been much more volatile in emerging market economies than in advanced economies (Catão and Sutton 2002, Catão and Kapur, 2004; Kaminsky, Reinhart, and Végh, 2004). Calculations reported by Catão and Kapur (2004) indicate that real GDP growth in a sample of 26 emerging market economies has a standard deviation of 4.5%, roughly double that for OECD countries.[22] Kaminsky, Reinhart, and Végh, (2004) report similar results—the standard deviation of real GDP growth in high-middle income countries over the period 1960-2003 is about double that in OECD countries (5.9% versus 3.1%). This is supported by our own calculations—real GDP growth in a sample of 29 emerging market economies has a standard deviation of about 4.1% over the period 1971-2004, almost double that in the G-7 countries (2.2%).

The standard deviation of output growth generated by the benchmark specification of the model has a standard deviation of 1.9%. The model is recalibrated by increasing the magnitude of the output shocks to the point where the standard deviation of output growth doubles (3.8%). Table 2 compares stochastic simulation results obtained using the benchmark specification and the recalibrated version of the model (simulations 1 and 2). Increasing output volatility raises the amount of variation in each of the four variables of interest but has no effect on average outcomes. The public debt burden is more sensitive to higher output volatility than is the external debt burden—the 90% confidence level for the public debt burden increases by 2.1 percentages points, while that for the external debt burden increases by only 0.7 of a percentage point.

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[22] Catão and Kapur (2004) also note that serial defaulters, defined as those emerging market economies that have either defaulted or rescheduled debt more than once over the period 1970-2001, have much higher output volatility than nondefaulters (5.8% versus 4.1%).

Table 2. Stochastic Simulation Results

steady-state conditions						
Simulation:	**1**	**2**	**3**	**4**	**5**	**6**
External debt						
Trade balance / GDP	0.00	0.00	1.37	1.37	1.37	1.37
External debt / GDP	32.0	32.0	32.0	32.0	32.0	32.0
Risk premium	0.00	0.00	4.00	4.00	4.00	4.00
Public debt						
Primary fiscal balance / GDP	0.00	0.00	0.65	0.65	0.65	0.65
Public debt / GDP	55.0	55.0	55.0	55.0	55.0	55.0
Risk premium	0.00	0.00	1.52	1.52	1.52	1.52
average levels in fifth year of projection horizon						
Simulation:	**1**	**2**	**3**	**4**	**5**	**6**
External debt						
Trade balance / GDP	0.00	0.00	1.37	1.37	1.70	2.08
External debt / GDP	32.0	32.0	32.0	32.0	31.8	31.1
Risk premium	0.00	0.00	4.00	4.00	4.35	4.28
Public debt						
Primary fiscal balance / GDP	0.00	0.00	0.65	0.65	1.09	1.17
Public debt / GDP	55.0	55.0	55.0	55.0	55.5	55.7
Risk premium	0.00	0.00	1.52	1.52	2.01	2.05
90% confidence levels in fifth year of projection horizon						
Simulation:	**1**	**2**	**3**	**4**	**5**	**6**
External debt						
Trade balance / GDP	3.3	3.7	5.1	4.9	5.1	6.0
External debt / GDP	41.4	42.2	42.3	44.1	43.0	42.0
Risk premium	4.00	4.00	4.00	4.00	7.98	7.96
Public debt						
Primary fiscal balance / GDP	1.1	1.7	2.6	3.7	5.8	6.2
Public debt / GDP	58.3	60.4	60.5	63.4	63.9	64.7
Risk premium	1.52	1.52	1.52	1.52	5.22	5.37
Standard deviation of real exchange rate	7.44	7.70	7.80	7.09	7.81	8.52

Constant risk premium

Recall that in the benchmark specification of the model there was no risk premium on either public or external debt. In simulation 3 we introduce a constant risk premium of 400 basis points on external debt, which raises the implicit interest rate on external debt above the rate of economic growth (r – g = 4%). A trade surplus of 1.37% of GDP is required to keep external debt at 32% of GDP in steady state. The risk premium on external debt also raises the cost of servicing public debt because a portion (38%) of public debt is held externally. The risk premium averaged across all public debt (held domestically and abroad) is 152 basis points (38% of 400 basis points). A primary fiscal surplus of 0.65% of GDP is required to keep public debt at 55% of GDP in steady state.

The implications of introducing a constant risk premium into the model can be seen by comparing results for simulations 2 and 3 reported in Table 2. The risk premium (included in simulation 3) has a relatively minor effect on the amount of variation in public and external debt, but has a sizable effect on the trade balance and the primary fiscal balance. The 90% confidence level for trade balance increases from 3.7% of GDP to 5.1%, but virtually all of the increase is due to the change in steady-state conditions—introducing the risk premium raises the steady state level of the trade balance from 0% of GDP to 1.37%. In other words, a constant risk premium (more generally, “r-g”) has important implications for the steady-state level of the trade balance due to conventional debt accumulation accounting, but has relatively minor implications for the amount of stochastic variation. A similar result holds for the primary fiscal balance.

Foreign-currency-denominated debt

In the benchmark specification of the model all public and external debt are denominated in domestic currency. This assumption is appropriate for most advanced countries, but not for emerging market economies, where external debt is largely denominated in foreign currency and in many cases a high proportion of domestic debt is indexed to the exchange rate.[23] We consider the case where all external debt and half of the public debt are denominated in foreign currency. This is included in simulation 4 reported in Table 2.

Incorporating foreign-currency-denominated debt into the model has larger effect on the public debt than on the external debt. This is because 90% of traded goods (exports and imports) in the model are priced in foreign currency, which provides a hedge against valuation effects (Hostland and Schembri, 2005). A large exchange rate depreciation raises the value of external debt significantly (measured in domestic currency), but also raises the value of exports significantly (measured in domestic currency), which improves the trade balance and offsets the increase in debt service costs. There is no similar hedging mechanism for public debt because revenues and expenditures are denominated in domestic currency.

Note that introducing foreign-currency-denominated debt slightly reduces the amount of variation in the trade balance. This counterintuitive result can be explained as follows. The valuation effect raises the amount of variability in the external debt burden. This is offset to some degree by the exchange rate mechanism, outlined above, which responds to limit deviations in the external debt burden from the initial level. The exchange rate response acts to stabilize the trade balance.

[23] The proportion of public debt indexed to the exchange rate varies greatly across emerging market economies and over time. For instance, in the case of Brazil, the proportion of domestic federal debt held by the public that is indexed to the exchange rate declined from 23% in December 1999 to almost 4% in May 2005.

Endogenous risk premium

We introduce an endogenous risk premium into the model by linking investors' perception of default risk to the debt burden. An increase in the debt burden makes investors less certain about the government's "willingness to repay" its debt obligations. A higher perceived risk of default gets priced into new issues of debt, which raises debt service costs and thereby adds to the debt burden. The model is calibrated such that a 10 percentage point increase in the debt burden raises the risk premium by 250 basis points. Hence, a 10 percentage point increase in the external debt burden would raise the risk premium from 400 to 650 basis points. Similarly, a 10 percentage point increase in public debt burden would increase the risk premium from 152 to 400 basis points. The endogenous risk premium on external debt has a 90% confidence level of almost 800 basis points (simulation 5 in Table 2), 400 basis points above the steady-state level (400 basis points). The endogenous risk premium on public debt has a 90% confidence level of 522 basis points, 370 basis points above the steady-state level (152 basis points).

Endogenizing risk premium into the model (comparing simulations 4 and 5 in Table 2) has a large effect on the primary fiscal balance but relatively little effect on public debt, external debt, and the trade balance. This is partly due to differences in the maturity structure of external and public debt. The maturity structure of public debt is much shorter than that for external debt, making the public debt service payments more sensitive to interest rate fluctuations. The result is also due to the nature of the fiscal policy rule. The endogenous risk premium amplifies the effect of shocks on the public debt burden, but the fiscal policy rule responds to these fluctuations. Discretionary spending is adjusted such that the debt burden reverts back to its initial level over the longer term. Larger fluctuations in the public debt burden require larger adjustments in discretionary spending, which raises the amount of variation in the primary fiscal balance.

Note that the endogenous risk premium reduces the amount of variation in the external debt burden. This counterintuitive result can be attributed to nonlinear interaction between the endogenous risk premium and the exchange rate. An increase in the endogenous risk premium raises debt service costs, which increases the external debt burden above the initial level. This triggers an exchange rate depreciation, which improves the trade balance. The improvement in the trade balance more than offsets the higher debt service costs so that the current account improves. In other words, higher debt service costs initiate an exchange rate response that acts to stabilize the current account and external debt burden.

The probability measures for projections of the fiscal variables are sensitive to the calibration of risk premium. To illustrate, we consider an alternative calibration where a 10 percentage point increase in the debt burden raises the risk premium by 150 basis points (instead of 250 basis points). The lower response of the risk premium reduces the 90% confidence level for the risk premium from 522 to 365 basis points and reduces that for the primary fiscal balance from 5.8% of GDP to 4.9%. This suggests that investors' subjective assessment of default risk plays an important role. One interpretation of the empirical findings by Reinhart, Rogoff, and Savastano (2003) is that the risk premium is more sensitive to increases in the debt burden in countries that have defaulted previously and/or have a bad track record in maintaining macroeconomic stability.

Our analysis assumes that emerging market economies cannot issue debt at yields below the "risk-free" rate so that the risk premium cannot be negative. This assumption introduces an asymmetry into the model, which affects the mean outcome of simulated variables. For example, the average risk premium on public debt is about 50 basis points above its steady-state level. Similarly, the average primary fiscal balance is 1.09% of GDP, which is above the steady-state level of 0.65%. The asymmetry raises both the average cost of servicing debt and the average amount of fiscal effort required to keep the debt burden from rising significantly.

"Sudden stops" in capital flows

Investors in the model are unwilling to lend when the risk premium exceeds 800 basis points. This financing constraint leads to a sudden stop in capital flows, which is accompanied by a large exchange rate depreciation to improve the current account. Introducing sudden stops into the model has a large effect on the volatility of the trade balance—its 90% confidence level increases from 5.1% to 6.0% of GDP (simulation 6 in Table 2). However, there is little effect on the volatility of the risk premium or the external debt burden. The intuition for this finding is as follows. The large exchange rate depreciation improves the trade balance, which more than offsets the valuation effect and therefore stabilizes the external debt burden. The higher volatility in the trade balance reflects its role in the external adjustment process which stabilizes the debt burden.

Introducing sudden stops into the model increases the volatility of the primary fiscal balance and the public debt burden. This is due to the valuation effect arising from the portion (one-half) of the public debt that is denominated in foreign currency. The large exchange rate depreciation raises the value of public debt and debt service payments (measured in domestic currency), but unlike the case of the external sector, there is no offsetting improvement in the primary fiscal balance because fiscal revenues and expenditures are denominated in domestic currency.

In order to determine whether our results are sensitive to the way in which sudden stops are modeled, we considered an alternative specification of the financing constraint whereby an increase in the risk premium above the threshold level (800 basis points) triggers an abrupt improvement in the current account. This entailed imposing the restriction that the current account must balance when the financing constraint binds.[24] This roughly corresponds to a 4.5 percentage point improvement in one year, which is broadly consistent with measures

[24] Calvo, Izquierdo, and Mejía (2004) model sudden stop episodes using the same current account constraint. Note that in general the magnitude of the current account reversal will depend on several factors, including the level of the current account when the finance constraint binds, the value of interest and debt maturing, the value of non-debt-creating capital flows, and changes in foreign reserves.

used in the empirical literature to define current account reversals.[25] It is also consistent with abrupt capital account and current account reversals during recent financial crises.[26] The simulation results generated using the current account constraint were found to be quite similar to those reported above. This is not surprising because the current account balance constraint is attained through a large exchange rate depreciation.[27] In short, there is little difference between modeling a sudden stop episode as a constraint on the current account, attained through a large exchange rate depreciation, or as a large depreciation, resulting in an improvement in the current account.

The results outlined above indicate that the pricing of traded goods and the adjustment of the exchange rate to changes in external debt both have a major influence on the sustainability of external debt. An exchange rate depreciation results in a rapid improvement in the trade balance in our model mainly because traded goods are priced in *foreign* currency. The adjustment largely occurs through trade prices, not volumes. In the case where exports are priced in *domestic* currency, the adjustment largely occurs through trade volumes. The empirical evidence indicates that trade volumes adjust more slowly than trade prices. This makes the trade balance respond more gradually to exchange rate changes.

To illustrate the importance of trade pricing, we compare simulations with exports priced in *foreign* versus *domestic* currency (simulations 6 and 6a, respectively, reported in Table 3). The simulation results indicate that pricing exports in *domestic* rather than *foreign* currency (simulation 6a versus 6) raises the amount of variability in the trade balance significantly—its 90% confidence level increases from 6.0% to 7.3% of GDP. When exports are priced in domestic currency, the response of the trade balance to the exchange rate is sensitive to the trade price elasticity. The elasticity must be large enough so that an exchange rate depreciation improves the current account, otherwise the solvency condition will be violated.[28] The solvency condition also depends on several other factors, including the debt burden, real interest rates, and the growth rate of potential output, all of which are influenced

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[25] Edwards (2004) considers two definitions of a current account reversal: one where the current account improves by at least 4 percentage points in one year; the other where it improves by at least 6 percentage points over three years.

[26] Calvo, Izquierdo, and Talvi (2003) report that capital flows to seven of the largest Latin American economies declined from over 5% of GDP in mid-1998 to less than 1% in just one year (Figure 2, p. 11); the current account in these countries improved from a deficit at 5% of GDP in mid-1998 to almost zero by the end of 2000 (Figure 3, p. 12).

[27] When the current account balance constraint binds, the exchange rate is no longer determined by interest rate parity, but instead becomes an endogenous variable to solve the model. A large, abrupt depreciation is required to generate a rapid improvement in the current account.

[28] This can be thought of in terms of “extended Marshal-Lerner conditions” (Hostland and Schembri, 2005).

by stochastic shocks. Thus, the stability conditions of the model evolve over time as the stochastic shocks displace the factors listed above.

We illustrate the importance of the exchange rate response to changes in external debt, which is determined by the following equation:

$$E_t\Delta q_{t+1} = (r_t - r^f_t) + \theta(E_t edebt_{t+1} - edebt^*) \qquad (1)$$

where $E_t\Delta q_{t+1}$ is the expected change in the real exchange rate,[29] $(r_t - r^f_t)$ is the domestic – foreign real interest rate differential, and $(E_t edebt_{t+1} - edebt^*)$ is the expected deviation in the external debt to GDP ratio from its steady-state level. In the case where $\theta = 0$, equation (1) is equivalent to an uncovered interest rate parity condition. The results reported for simulation 6 were generated with θ set to a value of 0.04, implying that a 10 percentage point increase in the debt burden above the initial level would result in a 4% depreciation of the real exchange rate. The exchange rate response acts to stabilize the external sector. This can be demonstrated empirically by simulating the model with θ set to 0.02 (instead of 0.04).[30] The results, given by simulation 6b, indicate that reducing the exchange rate response raises the amount of variability in the trade balance significantly—its 90% confidence level increases from 6.0% to 7.0% of GDP.

Note that simulation 6 exhibits higher volatility in the real exchange rate (measured by its standard deviation) than simulation 6b, but lower variation in the trade balance. This illustrates that it is the nature of the exchange rate volatility, not the magnitude, that affects the vulnerability of the external sector.

Simulation 6c combines these two factors—exports are priced in domestic currency and the exchange rate response is muted. These two factors together amplify the amount of variation in the trade balance—its 90% confidence interval increases from 6.0% to 8.4% of GDP. Moreover, the incidence of sudden stops (episodes where the risk premium exceeds 800 basis points) increases from 3.8% to 6.3%.

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[29] The nominal exchange rate is defined as the price of foreign exchange so that an increase in q implies a depreciation.

[30] The debt insolvency condition is often violated when θ is set to a value lower than 0.02. Given our preference not to incorporate debt write-down rules into this stage of research, we focus on parameterizations of the model that respect the debt solvency condition.

Table 3. Stochastic Simulation Results—Sensitivity Analysis

Simulation:	6[1]	6a[2]	6b[3]	6c[4]
average levels in fifth year of projection horizon				
External debt				
Trade balance / GDP	2.08	2.11	2.41	2.53
External debt / GDP	31.1	31.3	31.1	31.4
Risk premium	4.28	4.44	4.43	4.63
Public debt				
Primary fiscal balance / GDP	1.17	1.20	1.38	1.40
Public debt / GDP	55.7	55.7	56.0	55.9
Risk premium	2.05	2.13	2.17	2.26
90% confidence levels in fifth year of projection horizon				
External debt				
Trade balance / GDP	6.0	7.3	7.0	8.4
External debt / GDP	42.0	44.4	44.3	46.8
Risk premium	7.96	8.75	8.80	9.58
Public debt				
Primary fiscal balance / GDP	6.2	6.4	6.3	6.6
Public debt / GDP	64.7	65.0	64.9	64.9
Risk premium	5.37	5.84	5.77	6.15
Incidence of sudden stops:[5]	3.8%	5.1%	4.7%	6.3%
Standard deviation of real exchange rate	8.52	8.79	7.64	8.51

Notes: 1. Exports priced in ***foreign*** *currency; "full" exchange rate response.*
2. Exports priced in ***domestic*** *currency.*
3. "Muted" exchange rate response to fluctuations in external debt burden.
4. Exports priced in domestic currency and "muted" exchange rate response
5. Percentage of simulations where sudden stop constraint was binding (risk premium exceeded 800 basis points).

Public debt burden

Earlier in the paper, we raised the question of whether emerging market economies with higher public debt burdens have become more vulnerable to adverse shocks. We examine this issue by raising the initial public debt level while keeping the external debt burden unchanged (implying that the increase in the public debt is financed domestically).

Increasing the initial public debt burden raises the steady-state level of debt service payments through two channels. A higher level of debt raises debt service costs through conventional debt accounting. It also raises the risk premium for the reasons discussed above, which augments debt service costs. A higher primary fiscal balance is required to keep the public debt burden constant in steady state. Increasing the initial level of public debt from 55% to 65% of GDP raises the primary fiscal balance from 0.65% to 2.23% of GDP. Increasing it further to 75% of GDP raises the primary fiscal balance to 4.60% of GDP.

The simulation results reported in Table 4 show raising the initial public debt burden from 55% of GDP to 65% has a significant effect on the amount of variation in the public debt and the primary fiscal balance. The 90% confidence level for the public debt burden increases from 64.7% to 77.6% of GDP, while that for the primary fiscal balance increases from 6.2% to 9.6% of GDP. Much of the increase in the 90% confidence level for the public debt burden (10 of the 13 percentage points) simply reflects the higher initial debt level. However, conventional debt accumulation accounting can only explain about half of the 3.5 percentage point increase in the 90% confidence level for the primary fiscal balance.

When the initial public debt burden is increased to 75% of GDP, the 90% confidence level for the public debt rises to almost 90% of GDP, while that for the primary fiscal balance increases to 13.7% of GDP. This is a situation where the fiscal constraints are likely to bind, implying a high probability of a debt distress episode.

Note as well that raising the initial public debt burden to 75% of GDP has a significant effect on average values of the simulated fiscal variables. This is because a higher public debt burden makes the model more nonlinear, which amplifies the asymmetric aspect of the risk premium. For instance, the risk premium averages almost 50 basis points above its steady-state level. Similarly, the average level of the simulated primary fiscal balance is 5.3% of GDP, 0.7 of a percentage point above its steady-state level. To put this into perspective, in 2004 only 2 out of a sample of 21 emerging market economies ran primary fiscal balances in excess of 5% of GDP.[31] This demonstrates that average outcomes from stochastic simulation experiments (a dynamic *stochastic* equilibrium) can deviate significantly from control solutions (a dynamic *nonstochastic* equilibrium). The deviations are larger in cases where countries are more vulnerable to adverse shocks because the nonlinearities are greater.

To sum up, the simulation results outlined above indicate that a number of factors have a significant effect on the amount of variation in the public debt burden and the primary fiscal balance. This raises the question of what the fiscal authority can do to manage these risks.

[31] This calculation is based on data compiled for IMF (2005).

Table 4. Stochastic Simulation Results with Different Levels of Initial Debt Burden

steady-state conditions			
Debt / GDP	*55%*	*65%*	*75%*
External debt			
Trade balance / GDP	1.37	1.37	1.37
External debt / GDP	32.0	32.0	32.0
Risk premium	4.00	4.00	4.00
Public debt			
Primary fiscal balance / GDP	0.65	2.23	4.60
Public debt / GDP	55.0	65.0	75.0
Risk premium	1.52	4.00	6.50
average levels in fifth year of projection horizon			
Debt / GDP	*55%*	*65%*	*75%*
External debt			
Trade balance / GDP	2.08	2.06	2.10
External debt / GDP	31.1	31.5	31.4
Risk premium	4.28	4.34	4.33
Public debt			
Primary fiscal balance / GDP	1.17	2.86	5.32
Public debt / GDP	55.7	66.1	76.3
Risk premium	2.05	4.28	6.99
90% confidence levels in fifth year of projection horizon			
Debt / GDP	*55%*	*65%*	*75%*
External debt			
Trade balance / GDP	6.0	6.1	6.1
External debt / GDP	42.0	42.0	41.6
Risk premium	7.96	8.50	8.86
Public debt			
Primary fiscal balance / GDP	6.2	9.6	13.7
Public debt / GDP	64.7	77.6	89.9
Risk premium	5.37	8.65	12.13
Standard deviation of real exchange rate	8.52	8.79	8.89

C. The Role of Fiscal Policy

We examine this issue by simulating the model under alternative fiscal policy rules. The purpose of our analysis is not to explain the setting of fiscal policy over the historical period but rather to investigate the properties of alternative strategies for fiscal planning under uncertainty about future economic and fiscal developments. The fiscal authority seeks to keep the public debt burden from rising significantly over the medium term. This entails cutting discretionary spending when the debt burden rises above its target level. The scope for reducing discretionary spending is limited, however. The required fiscal adjustment hence runs the risk of having to cut taxes and/or renege on multi-period spending commitments (Georges and Moreau, 2002a and 2002b). Moreover, cutting spending in response to adverse shocks implies a pro-cyclical fiscal policy stance. In sum, the fiscal authority faces a trade-off between its objective to keep the debt burden from rising significantly and its other objectives, namely tax smoothing, honoring multi-period spending commitments and economic stabilization (Hostland and Matier, 2001; Hemming and Petrie, 2002; Perry, 2004).

Fiscal policy rules

The fiscal authority in the model strikes a balance between its conflicting policy objectives by using a "flexible debt" rule of the form:

$$(dpbal_t - dpbal^*) = \lambda(E_t pdebt_{t+1} - pdebt^*) \qquad (2)$$

where $dpbal_t$ is the discretionary component of the primary fiscal balance, $dpbal^*$ is its steady-state level, $E_t pdebt_{t+1}$ is the expected level of the public debt in the coming fiscal year, and $pdebt^*$ is its target level. All variables are expressed as proportions of GDP. The parameter λ determines the rate at which the projected public debt burden reverts to its target level in response to a shock. A higher value of λ implies a more rapid rate of adjustment, which reduces the amount of variation in the debt burden, but increases the amount of variation in the primary fiscal balance and results in a more pro-cyclical overall fiscal policy stance.

The fiscal policy trade-off outlined above can be illustrated by the simulation results reported in Table 5 below. Simulations 2, 3, and 4 were generated using a flexible debt rule (1) with λ set to values of 0.1, 0.3, and 0.5, respectively. The results indicate that raising λ over the range 0.1 to 0.5 improves the degree of debt control – the 90% confidence interval for the public debt burden declines from about 70% to 62%, but requires larger fluctuations in the primary fiscal balance (as indicated by the 90% confidence level which increases from 5.6% to 6.3% of GDP). Note that the fiscal policy rule has a major influence on the risk premium—raising λ from 0.1 to 0.5 reduces the 90% confidence interval for the risk premium 704 to 462 basis points. This in turn reduces the incidence of sudden stops (episodes where the risk premium exceeds 800 basis points) from 5.1% to 3.5%.

A "strict debt rule" (simulation 5) can be considered the extreme case where λ approaches infinity. Under this rule the fiscal authority responds to shocks by adjusting discretionary spending to a level that brings the projected debt burden back to the target level over the coming year. This results in a high degree of debt control—the 90% confidence level for the public debt burden is 56.8%, but requires a high degree of flexibility in the primary fiscal balance (the 90% confidence level is 7.1% of GDP).

We also consider a more conventional fiscal planning strategy that has received much attention in policy debates. Under a "cyclically-adjusted budget balance" rule (simulation 1), the fiscal authority aims to keep the overall budget deficit at 4.35% of GDP over the five-year planning horizon,[32] but does not respond to transitory deviations attributed to business cycle fluctuations. This rule is dominated by the flexible debt rule with λ set to 0.3 (or higher, 0.5) because it results in less debt control and requires a higher degree of flexibility in the primary fiscal balance. This demonstrates the benefit of incorporating both stock and flow dimensions into the fiscal planning process.

Table 5. Stochastic Simulation Results under Alternative Fiscal Policy Rules

Simulations:	**1**	**2**	**3**	**4**	**5**
	average levels in fifth year of projection horizon				
	Balanced budget rule	*Flexible debt rules*			*Strict debt target*
External debt					
Trade balance / GDP	2.1	2.1	2.1	2.0	1.8
External debt / GDP	31.6	31.3	31.1	31.6	31.8
Risk premium	4.45	4.50	4.28	4.27	4.08
Public debt					
Primary fiscal balance / GDP	1.4	1.2	1.2	1.1	0.8
Public debt / GDP	55.6	56.1	55.7	55.4	55.0
Risk premium	2.19	2.35	2.05	1.91	1.55
	90% confidence levels in fifth year of projection horizon				
	Balanced budget rule	*Flexible debt rules*			*Strict debt target*
External debt					
Trade balance / GDP	6.0	6.1	6.0	5.8	5.4
External debt / GDP	42.1	41.6	42.0	42.4	43.6
Risk premium	8.25	8.79	7.96	7.63	6.95
Public debt					
Primary fiscal balance / GDP	6.4	5.6	6.2	6.3	7.1
Public debt / GDP	67.0	69.9	64.7	62.0	56.8
Risk premium	5.98	7.04	5.37	4.62	2.64
Incidence of sudden stops: [1]	4.6%	5.1%	3.8%	3.5%	1.3%

Note: 1. Percentage of simulations where sudden stop constraint was binding (risk premium exceeded 800 basis points).

V. Conclusions

This paper demonstrates the value of stochastic simulation methods in helping to assess debt sustainability in emerging market economies. The stochastic simulation experiments provide probability measures for projections of the debt burden over a medium-term projection horizon, which help in assessing the vulnerability of emerging market economies to adverse shocks. Our simulation results indicate that a number of interrelated factors are important, including the volatility of output, financial fragility (reliance on short-term, foreign currency

[32] This is the steady-state level of the budget balance consistent with a debt to GDP ratio of 55%.

borrowing), the endogenous response of the risk premium, and sudden stops in private capital flows.

The factors listed above have a major influence on the vulnerability of public debt; the vulnerability of external debt is sensitive to the determination of the exchange rate and to the pricing of traded goods. The exchange rate in our model plays an important stabilizing role in the external sector. This suggests that exchange rate determination plays a critical role in assessing the sustainability of external debt and raises the empirical question of whether exchange rates in emerging market economies adjust in such a manner. We view this as an important area for future research. Trade pricing also plays a key role in assessing the sustainability of external debt. Our results show that pricing exports in foreign currency provides a hedge against large exchange rate movements, which stabilizes the external debt burden. There is no similar mechanism for the public debt (because fiscal expenditures and revenues are denominated in domestic currency).

The results outlined above suggest that the buildup in public debt burdens in some emerging market economies over the past few years merits close attention going forward. This raises the question of what role policy can play to help manage the risks. We show that fiscal policy can act in a preemptive manner to prevent the debt burden from rising over the medium term. However, this requires flexibility in fiscal planning, which many emerging market economies lack, given their limited capacity to generate tax revenues, their need for investment in public infrastructure, and the large proportion of nondiscretionary fiscal expenditures (particularly on health, education, and public pensions). Emerging market economies therefore face a difficult trade-off between managing the risk of a public debt crisis and other important fiscal policy objectives. This might explain why emerging market economies are more prone to episodes of debt distress. We leave this conjecture as another important avenue for future research.

Although much of our analysis focuses on fiscal policy, this should not be interpreted to imply that fiscal imbalances are the only determinant of debt crises. Several factors omitted from our study have played an important role.[33] For example, some debt crises originated in banking and corporate sectors, and in many cases later became liabilities of the public sector.[34] Explaining the origins of debt crises is clearly beyond the scope of our analysis. It would be of great interest, however, to incorporate contingent liabilities into our analysis of fiscal risk.

Our analysis has also omitted elements that reduce the risk of a debt crisis. The large swing in current account balances from a deficit to a surplus position over the past five years, along with the tremendous buildup of foreign reserves, has made most emerging market economies

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[33] Manasse and Roubini (2005) emphasize important differences between debt distress episodes.

[34] Calvo, Izquierdo, and Mejía (2004) show that liability dollarization in the domestic banking sector is a key determinant of sudden stops.

less vulnerable to sudden stops in capital flows. We have also omitted non-debt-creating capital flows, namely foreign direct investment and portfolio equity, as well as worker remittances, which have been significant in many emerging market economies.[35] Furthermore, capital outflows have increased significantly over the past few years in many emerging market economies as they have become more closely integrated with each other and with advanced economies. Valuation effects arising from exchange rate movements have become more complicated as a consequence. A more extensive analysis is needed to develop our understanding of how the various elements mentioned above influence the risk of debt default in emerging market economies.

The reduced-form macroeconomic structure underlying our analysis serves to ease the computational burden of stochastic simulation methods and facilitate calibration of the model. We view this simplification as the first stage of a longer-term research agenda on model development. It would be of great interest to extend the analysis to include a well-defined macroeconomic structure based on a choice-theoretic, optimizing intertemporal framework (such as the Global Economy Model, GEM, developed at the Fund). Another important advancement would be to endogenize the risk premium in a model-consistent manner to improve our understanding of how changes in economic fundamentals influence investors' assessment of risk. Much of our analysis has focused on default risk from the perspective of crisis prevention. The methodology followed in the paper can also be applied to crisis resolution. To do this, one would need to incorporate a rule for resolving debt defaults into a stochastic simulation framework. This innovation would enable one to develop a more complete assessment of default risk that would include the probability of debt default and the expected return given default. One could then derive measures of default risk in a model-consistent manner. Moreover, fiscal policy constraints play an important role in assessing default risk. In applying DSAs to specific countries, one needs to take into account fiscal constraints associated with limits on raising tax capacity and reducing nondiscretionary spending, as well as the longer-run growth implications of raising distortionary taxes and cutting spending in productive public infrastructure.

This paper has examined debt sustainability with reference to a fictional "generic" emerging market economy. For operational purposes, the analysis needs to be tailored to the characteristics of individual countries. Part of this is relatively straightforward—our model can be easily recalibrated for country-specific values of the public and external debt burdens, the maturity structure of public and external debt, the portion of external and public debt denominated in foreign currency, and more. Modifying the behavioral parameters to match the structural characteristics of individual countries represents a more difficult challenge.

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[35] In 2004, FDI inflows to all developing countries averaged 2.2% of GDP in 2004, while workers' remittances averaged 1.7% of GDP.

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