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Sources of Debt Accumulation in a Small Open Economy

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Abstract

This paper analyzes the borrowing behavior of a small open economy of a developing country that relies heavily on imports for its capital formation and faces an upward-sloping supply function of foreign loans. Decision makers face uncertainty about the longevity of external shocks. That uncertainty generates forecast errors that lead to substantial debt accumulation. It is found that the assumption of an upward-sloping supply function of foreign loans, which is a more realistic formulation for developing countries than the usual perfect elasticity, offers an alternative to the Uzawa-type utility function for analyzing asset accumulation in the small open economy framework.

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Keywords: Debt Accumulation, Stochastic Dynamic General Equilibrium Model, External Shocks, Incomplete Information, Developing Countries

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SUMMARY

It is widely believed that developing countries borrowed heavily on international financial markets based on the perception that the favorable external environment (low world interest rates and increasing commodity prices) of the 1970s would last. But, the commodity price booms of the mid- and late 1970s were short-lived and the period of low interest rates ended by the early 1980s. To what extent did uncertainty about the external environment contribute to developing countries' debt accumulation? It is reasonable to believe that their borrowing behavior will depend crucially on the perceived longevity of shocks.

This paper analyzes the borrowing behavior of a small open economy that is subject to terms of trade and world interest rate shocks in an environment where policy makers face uncertainty about the longevity of shocks. In particular, the analysis focuses on the conditions under which an optimistic view (that is alleged to have prevailed among developing countries during the debt accumulation period) about the longevity of external shocks, leading to overestimating the longevity of positive external shocks or underestimating the longevity of negative external shocks, can lead to significant debt accumulation. It is found that this optimistic view is compatible with rational behavior and can generate persistent overborrowing, making debt accumulation likely.

I. INTRODUCTION

In policy debates it is often argued that the foreign debt build-up by developing countries was essentially the result of their overborrowing and private banks over lending.[2] If this argument is true, we must understand why developing countries and private banks exhibited this excessive behavior. The usual supply-side explanation is that overborrowing during the 1970s was the result of very large OPEC surpluses searching for investment opportunities. The usual demand-side explanation is that overborrowing resulted from developing countries' high growth, improving terms of trade, and low world interest rates. It is also widely believed that developing countries borrowed heavily on international financial markets based on the perception that this favorable external environment would last.[3] But, the commodity price booms of the mid- and late 1970s were short-lived and the period of low interest rates ended by the early 1980s.

To what extent did uncertainty about the external environment contribute to developing countries' debt accumulation? It is reasonable to believe that their borrowing behavior will depend crucially on the perceived longevity of shocks. This paper analyzes the borrowing behavior of a small open economy that is subject to terms of trade and world interest rate shocks in an environment where policy makers face uncertainty about the longevity of shocks. In particular, the analysis focuses on the conditions under which an optimistic view (that is alleged to have prevailed among developing countries during the debt accumulation period) about the longevity of external shocks, leading to overestimating the longevity of positive external shocks or underestimating the longevity of negative external shocks, can lead to significant debt accumulation.

It is found that this optimistic view is compatible with rational behavior and can generate persistent overborrowing, making debt accumulation likely. The paper does not argue that debt accumulation is nonoptimal. In fact, it is shown that debt accumulation may arise as a rational response to uncertainty in international markets. However, debt accumulation increases the vulnerability of the debtor to interest rate fluctuations, as was documented dramatically during the debt crisis. The paper also does not argue that uncertainty was the main cause of debt accumulation in developing countries. Rather, it may have been simply a contributing factor. The justification for focusing on terms of trade and world interest rate shocks is twofold. First, the terms of trade determine the purchasing power of developing countries' exports. Scarce foreign exchange is essential for development because developing countries rely on imports of investment goods for their capital formation. Second, world interest rates determine both the cost of new borrowing and the cost of servicing the debt outstanding.

The framework used is a stochastic dynamic general equilibrium model that captures some important characteristics of developing economies. The stylized developing economy relies heavily on imports for capital formation and has imperfect access to international financial markets in the

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[2]"Overborrowing" refers to levels of borrowing higher than the *optimal* level, which will be defined precisely later in the paper.

[3]The external environment of a small open economy, which will be modeled below, is fully characterized by the evolution of terms of trade and the world interest rate. Henceforth, external shocks will refer to terms of trade and world interest rate shocks.

sense that the economy faces an upward-sloping supply function of foreign loans. This assumption has strong empirical support. It also offers an interesting alternative to the Uzawa-type utility function for analyzing asset accumulation in a small open economy. Finally, the model economy is characterized by an imperfect information structure where decision makers are uncertain about the longevity of external shocks.

The contribution of this paper is threefold. First, a dynamic general equilibrium model is developed that replicates fairly well the business cycle properties of the developing countries' data. Second, it is shown that uncertainty concerning the longevity of shocks (which is a very relevant type of uncertainty, especially for developing countries) generates forecast errors that are autocorrelated in a way that is similar to Bayesian learning in the "peso problem" (Lewis 1989). These autocorrelated errors can generate substantial debt accumulation. Third, it is not possible to analyze foreign asset accumulation with a variable interest rate within the standard small open economy framework. Under the usual assumption of a fixed discount factor, and given that the world interest rate is exogenous to the small open economy, the rate of time preference must equal the world interest rate to ensure the existence of a stationary equilibrium.[4]

Obstfeld (1982), following Uzawa (1968), solved this problem by endogenizing the time preference parameter, making it a function of the utility level. More recently, Mendoza (1995) used this approach in the context of a real business cycle model of a small open economy. The approach implies that the steady-state utility level is exogenously determined, leading to a saving target, that is, regardless of the nature and size of the exogenous shock, the economy will save enough to achieve the fixed steady-state utility level. Another approach, attributed to Blanchard (1985) and applied in the context of a small open economy by Cardia (1991), is to assume a finite probability of death. Then, the world interest rate and the subjective discount rate do not necessarily have to be equal, and the difference between them becomes a function of financial wealth.

This paper explores an alternative approach. Instead of making the time preference vary in order to generate well-defined dynamics around a stationary equilibrium, it is the domestic interest rate that adjusts so as to equalize the time preference and the marginal cost of borrowing in equilibrium. This adjustment will be achieved by assuming an upward-sloping supply function of foreign loans, which is a more realistic assumption for developing countries than the usual perfectly elastic alternative. "... developing countries typically face an upward-rising supply curve of capital funds." Harberger (1985, p. 236).

The reminder of the paper is organized as follows. Section II develops the model. Section III describes briefly the solution procedure and the model calibration, and section IV presents the results. Some concluding observations are contained in the final sections.

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[4]See Sen (1994) and chapter 9 of Turnovsky (1995) for good discussions of this problem in the deterministic case.

II. THE MODEL

The model outlined below is a stochastic growth model of a small open economy. There are two goods, a domestic and a foreign good. The foreign good is taken to be the numeraire.

A. Preferences

Consumer preferences are represented by a utility function of the constant-relative-risk-aversion type. The representative consumer draws utility from the domestic and foreign goods, earns income from labor services (supplied inelastically) and from renting capital to the firms producing the domestic good. Consumers maximize the expected value of their lifetime utility:[5]

$$W = E_0 \sum_{t=0}^{\infty} \beta^t [ch_t^\mu cm_t^{1-\mu}]^\gamma / \gamma \qquad \gamma < 1, \tag{1}$$

where W is the expected lifetime utility, ch_t is consumption of the domestic good, cm_t is consumption of the imported good, β is the discounting factor, μ is the share of the domestic good in consumption, and $1-\gamma$ is the level of relative risk aversion.

B. Technology

The technology for the production of the domestic good is represented by a constant-elasticity-of-substitution production function. The domestic good is produced under constant returns to scale:

$$y_t = B[\lambda k_t^\alpha + (1-\lambda) l_t^\alpha]^{1/\alpha} \qquad \alpha \leq 1 , \tag{2}$$

where y_t is the production of the domestic good, k_t is the capital stock, l_t is total labor services, and λ and $(1-\lambda)$ are the shares of capital and labor in output, respectively. The elasticity of substitution between capital and labor is $1/(1-\alpha)$. The home good can be consumed, invested, or exported:

$$ch_t + ih_t + yx_t \leq y_t \tag{3}$$

where ch_t, ih_t, and yx_t are the quantities of the home good going to domestic consumption, to investment and to exports, respectively.

The investment good is a composite of the domestic and foreign goods. In order to capture developing countries' heavy dependence on imports of investment goods, zero substitutability between domestic and foreign investment goods is imposed:

$$i_t = \min [\phi ih_t, \eta im_t], \tag{4}$$

where i_t is gross national investment, ih_t and im_t are the domestic and foreign content of gross national investment, and $1/\phi$ and $1/\eta$ are the shares of the domestic and imported investment

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[5]This formulation assumes implicitly that individuals do not value leisure. This assumption is used widely in the development economics literature to capture the view that leisure is a luxury good for developing countries households and thus is much less valued than consumption.

inputs. The price of the investment good in terms of the numeraire can be obtained by computing its unit cost. This yields: $pi_t = px_t/\phi + 1/\eta$. Following the common practice in the real business cycle literature, quadratic adjustment costs on investment are imposed in order to keep the relative volatility of investment at a realistic level:

$$\frac{\theta}{2}(k_{t+1} - k_t)^2$$

(5)

C. International financial markets

The aim is to capture, in a simple way, the existence of an upward-sloping supply function of foreign loans. This would arise, for example, in the imperfect information framework of Stiglitz and Weiss (1981), in which the interest rate increases with the debt level until the latter reaches a threshold beyond which the debtor will be denied credit (in the case with no uncertainty).

The domestic real interest rate on foreign debt, in terms of imports, is assumed to be the sum of two components, the world interest rate and a spread that is increasing in a solvability indicator defined as the exponential of minus the debt-exports ratio:

$$r_t = rw_t + \exp(-\pi\, b_t/px_t yx_t) \qquad \pi > 0,$$

(6)

where r_t is the domestic real interest rate in terms of imports, rw_t is the world risk free real interest rate, b_t is the debt level, px_t is the terms of trade, and yx_t is the quantity exported. The coefficient π determines the slope of the supply function of foreign funds.[6] The supply can be made arbitrarily close to the usual perfectly elastic formulation by choosing π that is very small. Interestingly, it can be shown that this upward-sloping supply function guarantees the existence of a stationary equilibrium by allowing the domestic interest rate to adjust so that in equilibrium the marginal cost of borrowing equals the rate of time preference.[7]

D. Information structure

In addition to uncertainty about the future terms of trade and world interest rate, decision makers also face uncertainty about the longevity of external shocks. This uncertainty is modeled as follows: external shocks are assumed to be the sum of two components, one permanent, the other transitory. Decision makers observe the sum but not the individual components. Thus they need to

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[6]This specification yields a positive spread for positive debt levels, which increases as the solvability ratio, measured by $b_t/px_t yx_t$ worsens (decreases). Note that this specification is inappropriate for the creditor case. However, this paper is concerned only with the debtor case (the case in which the time preference of the developing country is greater than the world interest rate).

[7]See Senhadji (1994). Lundvik (1993) used a similar assumption in a real business cycle model of a small open economy.

solve a signal extraction problem, that is they need to infer the permanent and transitory components from their sum.[8] Formally,

$$px_t = pxp_t + pxt_t + \overline{px} \quad and \quad rw_t = rwp_t + rwt_t + \overline{rw}, \tag{7}$$

where pxp_t and rwp_t are the permanent components, pxt_t and rwt_t are the transitory components, and $\overline{px}$ and $\overline{rw}$ are the unconditional means of the terms of trade and the world interest rate, respectively. The permanent components are assumed to follow a random walk and the transitory components a white noise process:

$$pxp_t = pxp_{t-1} + \epsilon_t^{pxp}, \quad E(\epsilon_t^{pxp})^2 = \sigma_{pxp}^2, \quad pxt_t \sim WN(0,\sigma_{pxt}^2) \tag{8}$$

$$rwp_t = rwp_{t-1} + \epsilon_t^{rwp}, \quad E(\epsilon_t^{rwp})^2 = \sigma_{rwp}^2, \quad rwt_t \sim WN(0,\sigma_{rwt}^2). \tag{9}$$

In vector notation:

$$\begin{pmatrix} px_t \\ rw_t \end{pmatrix} = \begin{pmatrix} pxp_t \\ rwp_t \end{pmatrix} + \begin{pmatrix} pxt_t \\ rwt_t \end{pmatrix} + \begin{pmatrix} \overline{px} \\ \overline{rw} \end{pmatrix}. \tag{10}$$

Decision makers observe $\chi_t = (px_t \ rw_t)'$, from which they extract an estimate of pxp_t, pxt_t, rwp_t and rwt_t. Their information structure is recursive and can therefore be represented in a convenient way employing the state space form. This form allows the use of Kalman filtering techniques. The certainty equivalence property of the quadratic approximation solution method, used to solve the model, implies separation of estimation and control. Consequently, the estimation and control problems can be solved sequentially.

As mentioned earlier, the solution to the estimation problem is easily derived by using the state space form. Let us define z_t, a 4x1 vector, as $z_t = (pxp_t \, pxt_t \, rwp_t \, rwt_t)'$. Note that z_t is a Markov process:

$$z_t = A z_{t-1} + \epsilon_t , \tag{11}$$

where:

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[8]This problem is the same as the one analyzed in Kydland and Prescott (1982) except that this is a one-stage extraction problem while theirs is a two-stage. A similar information structure has also been used in Christiano (1988).

$$A = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}, \quad \epsilon_t = \begin{pmatrix} \epsilon_t^{pxp} \\ pxt_t \\ \epsilon_t^{rwp} \\ rwt_t \end{pmatrix} \sim N(0, V_\epsilon),$$ (12)

$$V_\epsilon = \begin{pmatrix} \sigma_{pxp}^2 & 0 & 0 & 0 \\ 0 & \sigma_{pxt}^2 & 0 & 0 \\ 0 & 0 & \sigma_{rwp}^2 & 0 \\ 0 & 0 & 0 & \sigma_{rwt}^2 \end{pmatrix}.$$ (13)

Decision makers do not observe z_t, the individual permanent and transitory components, but χ_t, the aggregate shock. To complete the state space representation, we need to express χ_t as a function of z_t:

$$\chi_t - \bar{\chi} = c z_t, \quad where \quad \bar{\chi} = (\bar{px} \ \bar{rw})' \quad and \quad c = \begin{pmatrix} 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \end{pmatrix}.$$ (14)

In the Kalman filtering literature, equations (11) and (14) are known as the transition and measurement equation. Let $\hat{z}_t$ be the expected value and Σ_t the covariance of the distribution of z_t conditional on χ_k for $k \leq t$. The Kalman filter yields an updating equation for the conditional mean of the permanent and transitory components of the terms of trade and world interest rate $(\hat{z}_t)$ and the Ricatti equation for the conditional variance of the forecast error (Σ_t). These two equations are:

$$\hat{z}_t = A\hat{z}_{t-1} + [c(A\Sigma_t A' + V_\epsilon)]' [c(A\Sigma_t A' + V_\epsilon)c']^{-1} [(\chi_t - \bar{\chi}) - cA\hat{z}_{t-1}]$$ (15)

$$\Sigma_t = A\Sigma_{t-1}A' + V_\epsilon [c(A\Sigma_{t-1}A' + V_\epsilon)]' [c(A\Sigma_{t-1}A' + V_\epsilon)c']^{-1} [c(A\Sigma_{t-1}A' + V_\epsilon)]$$ (16)

The interpretation of equations (15) and (16) is intuitive. The estimated conditional mean of z_t is updated, as new information becomes available by adding to the previous estimate, $\hat{z}_{t-1}$, the forecast error, $((\chi_t - \bar{\chi}) - cA\hat{z}_{t-1}$, weighted by $[c(A\Sigma_{t-1}A' + V_\epsilon)]' [c(A\Sigma_{t-1}A' + V_\epsilon)c']^{-1}$, which is the *gain matrix*. The vector $\hat{z}_t$ is a sufficient statistic for estimating z_τ, $\tau \geq t$.

The next step is to solve the control problem conditional on the transition and measurement equations, and on the law of motion of the state vector estimate, $\hat{z}_t$, along with its condtional variance. Assuming that the central bank charges individual borrowers the marginal cost of borrowing. The second welfare theorem applies, and the competitive equilibrium can be obtained by solving the following social planning problem:[9]

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[9]The equivalent decentralized economy, giving households and firms individual optimization problems, is relatively straightforward and therefore has been omitted.

Equilibrium

$$\underset{\{y_t\}_{t=0}^{t=\infty}}{MAX} \quad W = E_0 \sum_{t=0}^{\infty} \beta^t \, (ch_t^{\mu} \, cm_t^{1-\mu})^{\gamma}/\gamma \qquad where \quad y_t=(ch_t \, cm_t \, ih_t \, im_t \, yx_t \, k_{t+1} \, b_{t+1}) \tag{17}$$

s.t.

$$b_{t+1} = (1+r_t)b_t + cm_t + im_t - px_t yx_t \qquad\qquad\qquad current \ account \tag{18}$$

$$ch_t + ih_t + yx_t \leq B[\lambda \, k_t^{\alpha} + (1-\lambda) \, l_t^{\alpha}]^{1/\alpha} \qquad\qquad\qquad resource \ constraint \tag{19}$$

$$k_{t+1} = (1-\delta)k_t + i_t - \frac{\theta}{2}(k_{t+1}-k_t)^2 \qquad\qquad\qquad law \ of \ motion \ for \ capital \tag{20}$$

$$i_t = min \, (\phi \, ih_t, \eta \, im_t) \qquad\qquad\qquad investment \tag{21}$$

$$l_t \leq \overline{l} \qquad\qquad\qquad labor \ constraint \tag{22}$$

$$r_t = rw_t + exp(-\pi \, b_t/px_t yx_t) \qquad\qquad\qquad domestic \ real \ interest \ rate \tag{23}$$

$$\lim_{t\to\infty} E_0 \prod_{j=0}^{t} (1/(1+r_j)) \, b_{t+1} = 0 \qquad\qquad\qquad tranversality \ condition \ for \ b_{t+1} \tag{24}$$

$$\lim_{t\to\infty} E_0 \prod_{j=0}^{t} (1/(1+r_j)) \, U_t' \, k_{t+1} = 0 \qquad\qquad\qquad tranversality \ condition \ for \ k_{t+1} \tag{25}$$

$$z_t = A \, z_{t-1} + \epsilon_t \qquad\qquad\qquad AR(1) \ for \ external \ shocks \tag{26}$$

$$\chi_t - \overline{\chi} = c \, z_t \qquad\qquad\qquad signal \ definition \tag{27}$$

$$\hat{z}_t = A\hat{z}_{t-1} + (c(A\Sigma_{t-1}A+V_{\epsilon}))' \, (c(A\Sigma_{t-1}A+V_{\epsilon})c')^{-1}((\chi_t-\overline{\chi}) - cA\hat{z}_{t-1}) \qquad conditional \ mean \ updating \ equation \tag{28}$$

$$\Sigma_t = A\Sigma_{t-1}A'+V_{\epsilon} \ (c(A\Sigma_{t-1}A'+V_{\epsilon}))' \, (c(A\Sigma_{t-1}A'+V_{\epsilon})c')^{-1} \\ c(A\Sigma_{t-1}A'+V_{\epsilon})) \qquad Ricatti \ equation \ for \ conditional \ variance \tag{29}$$

z_0, k_0 and b_0 are given.

Notation:

W:	Expected lifetime utility.
U_t':	Marginal utility of the composite good at time t.
β:	Discounting factor, $0 < \beta < 1$.
cm_t:	Consumption of the imported good.
ch_t:	Consumption of the domestic good.
im_t:	Import content of investment.
ih_t:	Domestic content of investment.
$1/\phi$:	Share of domestic investment inputs in gross national investment.
$1/\eta$:	Share of foreign investment inputs in gross national investment.
i_t:	Gross national investment.
δ:	Capital depreciation rate.
l_t:	Labor input in the production of the domestic good.
y_t:	Output of the domestic good.
yx_t:	Export quantity.
k_{t+1}:	Stock of capital next period.
b_{t+1}:	Stock of foreign debt next period.
r_t:	Domestic real interest.
rw_t:	World real interest rate.
rwp_t, rwt_t:	Permanent and transitory components of the world interest rate.
$\overline{rwpx}$	Unconditional mean of the world interest rate.
s_t:	Spread over the world interest rate which is a function of the debt level.
π:	Determines the slope of the spread.
θ:	Adjustment cost parameter.
px_t:	Terms of trade (import good is the numeraire).
pxp_t, pxt_t:	Permanent and transitory components of terms of trade.
$\overline{px}$	Unconditional mean of terms of trade.
z_t:	4x1 vector containing the permanent and transitory components of terms of trade and world interest rate.
Σ:	4x4 conditional variance-covariance matrix of z_t.
A:	4x4 coefficient matrix of the AR(1) process describing the permanent and transitory components of terms of trade and world interest rate.
ϵ_t:	4x1 vector of innovations to the permanent and transitory components of terms of trade and world interest rate.
V_ϵ:	Variance-covariance matrix of ϵ_t.
σ_{pxp}, σ_{pxt}:	Standard deviation of the permanent and transitory components of px_t.
σ_{rwp}, σ_{rwp}:	Standard deviation of the permanent and transitory components of rw_t.

III. SOLUTION METHOD AND CALIBRATION

This model cannot be solved analytically. Therefore, the solution will be obtained numerically, using the linear-quadratic method. Kydland and Prescott (1982) first introduced this method for approximating the solution of stochastic nonlinear optimization problems. This method and an equivalent one, introduced by King, Plosser and Rebelo (1988), which consists of linearizing the decision rules, have been applied in numerous studies.[10] The linear-quadratic method is described in detail in Hansen and Prescott (1995). It has been shown to be quite accurate for the neoclassical stochastic growth model (Christiano 1990) when shocks have a small variance. Since the approximated value function is quadratic and the constraints (not substituted in the value function) are linear, the decision rules are linear. Note that the concavity of both the utility function and the production function ensures that the second-order conditions of the maximization problem are satisfied.

Before simulating the model, it is necessary to calibrate its parameters. The data set contains thirty-five developing countries. Instead of choosing a particular country, the model is calibrated for a "representative" economy, which is the median of the thirty-five. Sensitivity analysis is conducted for some key parameters. In Taylor (1990) the share of capital goods and intermediate inputs in total imports is approximately 75 percent for a sample of eleven developing countries. Therefore, the domestic content share, $1/\phi$, and the foreign content share, $1/\eta$, of investment are set equal to 0.25 and 0.75, respectively. These shares reflect the heavy dependence of developing countries on foreign investment goods. Given the large share of imports used for investment, the share of imports for consumption, μ, is set at approximately 10 percent. The elasticity of substitution between capital and labor is chosen so that the steady-state investment-GDP ratio is 21 percent, which is the mean of the thirty-five countries. This implies a value of -1 for α or an elasticity of substitution, $1/(1-\alpha)$, of 0.5. A capital depreciation rate of 10 percent and a capital share of 30 percent are standard values, which yield a reasonable capital-output ratio of 2.1.

The adjustment cost parameter, θ, is equal to 0.1. This parameter value implies an adjustment cost expressed in terms of investment equal to 0.02 percent. Rossi's (1988) detailed empirical study on the behavior of liquidity-constrained consumers in developing countries reports estimates of the risk aversion parameter, γ. Unfortunately, the estimates are imprecise, especially for Latin America. They range from -0.02 to -10.23, with a mean of approximately -3, which is the value used in calibrating the model.[11] Sensitivity analysis shows that the qualitative results of the model are not very sensitive to this parameter. The discounting factor, β, and the spread parameter, π, are used to replicate the level of the spread and the debt-GDP ratio in the data. The spread is 1.5 percent (which is the difference between the median real interest rate on the foreign debt of 5.5 percent, reported in the last column of Table 2, and the historical real interest rate of 4 percent for the U.S.). The debt-GDP ratio is approximately 50 percent (which is the mean during the sample period). This implies a value for β and π of 0.90 and 8.35, respectively.

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[10]For a recent application of the linearization method, see Kollmann (1996).

[11]Rossi (1988), tables 1-6, column 2.

The modeling of the information structure outlined above requires that, terms of trade shocks and real interest rate shocks (hereafter px and rw shocks) be the sum of two components, one permanent and the other transitory. The key parameter is the relative size of the permanent component (q), that is the ratio of the standard deviation of the random walk innovation to the standard deviation of the transitory component, which is estimated using an unobserved-components model. Table 1 shows q for px and rw for a subsample of countries for which the maximum likelihood routine converged.[12] The average q is 0.33 and 0.23 for px and rw, respectively. The unconditional means $\bar{px}$ and $\bar{rw}$ are 1 and 0.04, respectively. Note that the time preference implied by the discount factor (1/β-1) is greater than the unconditional mean of the world interest rate. This implies that the small country tends to be a net borrower.[13] The following table summarizes the calibration of the model:

Param.		Definition	Value
$1/\eta$	:	Share of imported investment good	.75
μ	:	Share of domestic good in consumption	.90
γ	:	Relative-risk-aversion parameter	-3.00
δ	:	Depreciation of capital	.10
λ	:	Share of capital	.30
θ	:	Adjustment cost parameter for investment	1.00
α	:	$(1/1-\alpha)$ is elasticity of substitution between capital and labor	.50
β	:	Discount factor	.90
π	:	Determines slope of supply function of foreign loans	8.35
ρ	:	Autocorrelation coefficient of total factor productivity	.80
$\sigma_{pxp}/\sigma_{pxt}$	:	Relative size of the permanent component for px	.33
$\sigma_{rwp}/\sigma_{rwt}$	:	Relative size of the permanent component for rw	.23

IV. RESULTS

A. Business cycle properties of the data and model

The variables analyzed are GDP; private consumption (c), gross domestic investment (i), exports and imports of goods and nonfactor services $(x$ and $m)$, net export (nx) defined as exports minus imports divided by exports with all three variables in current prices; the current account divided by exports (ca); the current stock of foreign debt (b), terms of trade (px) defined as the implicit exports deflator divided by the imports deflator; and the real interest rate on total debt (r),

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[12]The variable rw is constructed as the LIBOR minus the growth rate of the individual countries' imports prices.

[13]Deaton (1991) argues that this assumption is more appropriate than the alternatives for developing countries.

defined as the average interest rate on total debt minus the growth rate of the imports price.[14] The variables GDP, c, i, x, m, b and r are expressed in terms of importables by deflating them by the imports price (which is the numeraire in the model). The source is World Data 1995 from the World Bank. All series are annual. The sample range is 1970-93 for ca,[15] 1971-93 for b and r,[16] and 1960-93 for the other series.[17] The data have been detrended using the H-P filter with the smoothing parameter $\lambda=100$.[18]

The business cycle properties of a variable are summarized by two statistics: its relative volatility, which is the ratio of its standard deviation to the standard deviation of GDP, and its comovement with GDP which is its correlation with GDP (Table 1). The table gives also the persistence of output and the stock of foreign debt as measured by their first autocorrelation coefficient.

The results in Table 1 can be summarized as follows: Unlike in developed countries, where consumption is smoother than income, in developing countries consumption is more volatile than income. This may reflect both more noise in developing countries' consumption data and their less-developed financial markets, offering less opportunity for consumption smoothing. The relative volatility of developing countries' investment is lower than that of developed countries. While exports, imports, net exports and terms of trade are all less volatile than aggregate output, the current account is much more volatile than GDP. Foreign debt and the real interest rate on total debt are as volatile as GDP. As expected, all four components of GDP (c, i, x, and m) are procyclical (they have a positive contemporaneous correlation with GDP). The variables nx and ca are weakly countercyclical (they have a negative contemporaneous correlation with GDP). Foreign debt is procyclical. The variable px is weakly procyclical, while r is weakly countercyclical. GDP and foreign debt have the same persistence on average.

The next step is to briefly compare the model's business cycle properties to the data. The discussion will focus on comparing the business cycle statistics for the benchmark model to the median of these statistics from the thirty-five country sample. The model replicates most of the business cycle properties in the data. It reproduces to some extent the high relative volatility of consumption and reproduces closely the relative volatility of investment. It overestimates the relative volatility of exports, imports, and net exports, and underestimates the relative volatility of the current account and terms of trade. It also replicates both the sign and the magnitude of the

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[14]A more appropriate measure of the cost of foreign debt would be the real interest rate on foreign debt, which is not available.

[15]Except Hong Kong 1970-91 and Zaïre 1971-90.

[16]Except Venezuela and Bangladesh, for which b has the sample range 1972-93, and Zaire, for which r has the range 1971-90.

[17]The exceptions are Brazil 1960-92, Côte d'Ivoire 1965-93, Ecuador 1965-93, Singapore 1975-93, Sri Lanka 1970-93, Sudan 1960-90, Tunisia 1961-93, Venezuela 1974-93 and Zaire 1960-89.

[18]The choice of $\lambda=100$ is consistent with previous work (See Correia, Neves, and Rebelo 1995 and Mendoza 1995).

contemporaneous correlation of these variables with GDP. It mimics the *procyclical* behavior of c, i, x, m, b and px and the *countercyclical* behavior of nx, ca and r. The model's only discrepancies with the data, as far as comovement is concerned, is the stronger procyclical behavior of consumption, which is typical in these aggregate models, and the weaker procyclical behavior of foreign debt. The model also replicates fairly well the persistence of GDP and foreign debt.

B. Decision rules and impulse response analysis

The solution to the linear-quadratic dynamic programming problem yields a set of three linear decision rules for b_{t+1}, k_{t+1}, and yx_t:

$$b_{t+1} = 1.30 + .75b_t - .22k_t + .26pxp_t - .72pxt - 1.16rwp_t + .90rwt_t - .33z_t \tag{30}$$

$$k_{t+1} = 1.56 - .08b_t + .69k_t + .21pxp_t - .07pxt - .61rwp_t - .02rwt_t + .48z_t \tag{31}$$

$$yx_t = -.11 + .28b_t + .08k_t - .47pxp_t + .11pxt + 1.35rwp_t + .14rwt_t + .64z_t \tag{32}$$

Note that the certainty equivalence property of the linear-quadratic solution method implies that the coefficients of these decision rules are identical for both the perfect information economy (where decision makers observe the state vector z_t) and the imperfect information economy (where decision makers do not observe the state vector z_t but compute an estimate $\hat{z}_t$). Equations (30)-(32) are written for the perfect information economy. For the imperfect information economy, simply replace z_t by $\hat{z}_t$.

A few points about these decision rules are worth mentioning. First, note that the coefficient on b_t in equation (31) is different from zero, which implies that the usual separation between capital accumulation and foreign debt in the small open economy framework does not hold due to the upward-sloping supply function of foreign loans. Second, the negative cross effect of both assets (the negative coefficient on b_t in k_{t+1} equation and the negative coefficient on k_t in b_{t+1} equation reflects the substitutability between physical capital and the foreign bond.[19]

Third, a negative external shock (that is, a deterioration in the terms of trade or an increase in the world interest rate) will trigger a different borrowing response depending on whether the shock is perceived to be permanent or transitory. A permanent negative shock will reduce foreign borrowing, while a transitory one will be smoothed out by additional foreign borrowing. This effect reflects simply the consumption-smoothing motive characteristic of these dynamic general equilibrium models.

Fourth, as far as the decision rule for the capital stock is concerned, an increase in the terms of trade affects the stock of capital through three channels. The first one is through the marginal product of capital. A transitory improvement in the terms of trade leaves next period's marginal product of capital intact (the only small effect is through the spread), while a permanent

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[19]A positive value of b_{t+1} means that the small open economy is a debtor on international financial markets. Therefore, a decrease in b_{t+1} means an increase in its portfolio of foreign bonds or, equivalently, a decrease in its short position in foreign bonds.

improvement increases the marginal product of capital and therefore stimulates investment. The second channel is through the price of investment, which is a weighted average of the price of the domestic and foreign good: $pi_t = px_t/\phi + 1/\eta$. A permanent improvement in the terms of trade will increase the price of investment, thus discouraging investment. The third channel is through a pure wealth effect coming from the purchasing value (in terms of the imported good) of the foreign exchange generated by the current trade balance.

Fifth, export volume (yx_t) increases to take advantage of a transitory improvement in the terms of trade but declines if the improvement is permanent. An increase in the world interest rate, especially a permanent increase, triggers a rise in exports in order to meet the higher servicing cost of the debt outstanding.

Once the decision rules are computed, one can compute the impulse response functions (IRF). The IRF of an endogenous variable traces out its dynamic response to exogenous shocks. Three exogenous shocks are examined: terms of trade, real interest rate, and productivity shocks. Both temporary and a permanent version of the first two shocks are analyzed (Figure 1).

A permanent increase in the terms of trade raises the marginal product of capital in terms of the numeraire, stimulating investment. As expected, consumption also responds positively resulting in an increase in GDP. On impact, exports increase more than imports, yielding a trade surplus that is reversed gradually, and then converges to zero. Foreign borrowing first falls before increasing progressively toward its new steady-state level. The investment price jumps directly after one period to its new steady-state level. The spread, which is a function of the debt-export ratio, follows closely the pattern of the debt level. Note that the effect on the spread is only transitory, even though the effect on exports and foreign debt is permanent. This implies that the cumulative response of debt-export ratio to a permanent terms of trade shock is zero. A temporary increase in terms of trade produces similar effects on these variables, except that all effects are transitory.

A permanent increase in the world interest rate depresses consumption and investment. Aggregate output falls only slightly because of the large trade surplus destined to pay for the higher servicing cost of the debt. The developing economy responds to the permanent increase in this cost by reducing new borrowing, which lowers the spread. Note that contrary to the case of a permanent increase in the terms of trade, the spread decreases permanently, implying that the cumulative response of the debt-export ratio to a permanent rise in the world interest rate is negative. A temporary increase in the world interest rate has similar but transitory effects.

While the terms of trade and the world interest rate are modeled as two-component stochastic processes (one permanent and the other transitory), total factor productivity is modeled as a one-component AR(1) process. Thus all productivity shocks have some persistence but are not permanent. Figure 2 shows that a favorable productivity shock spurs an increase in investment, consumption, and GDP. Imports and exports, in particular, rise leading to a trade surplus. This surplus reverts to a trade deficit as exports move toward their steady-state level faster than imports. Some of the trade surplus goes to reduce the foreign debt, improving the solvability ratio b_t/px_tyx_t and therefore reducing the spread.

C. Borrowing behavior under perfect and imperfect information

This sub-section analyzes conditions under which imperfect information about the longevity of terms of trade and world interest rate shocks lead to overborrowing. In the perfect information economy the decision-maker is assumed to observe the permanent and transitory components of the terms of trade and world interest rate, while in the imperfect information economy, the decision-maker observes their sum, from which she extracts an estimate of the individual components. Overborrowing is defined as the excess of foreign debt in the imperfect information economy over the foreign debt in the perfect information economy. Thus overborrowing may occur either because there is more borrowing in the imperfect information economy than in the perfect information economy or because imperfect information prevents decision-makers from reducing the debt when it is optimal to do so. *The decision rule for foreign debt, equation (30), implies that overborrowing will occur if a permanent decline in the terms of trade is perceived to be transitory or if a transitory improvement in the terms of trade is believed to be permanent. Similarly, overborrowing will occur if a permanent increase in the world interest rate is believed to be transitory or if a transitory decline in the world interest rate is believed to be permanent.* When agents face uncertainty about the longevity of a shock, overborrowing may result even if they are rational. It is shown below that this type of uncertainty generates forecast errors that are autocorrelated. Therefore, when overborrowing occurs it can be persistent, permitting debt accumulation.

Note that the decision rules for b_{t+1} and k_{t+1} form a vector autoregression of order 2. It can be written as:

$$y_{t+1} = \Phi_0 + \Phi_1 y_t + \Phi_2 z_t \tag{33}$$

where Φ_0, Φ_1 and Φ_2 are a 2x1 vector, a 2x2 matrix, and a 1x4 vector of coefficients, respectively; $y_t = (b_t \ k_t)'$; and $z_t = (pxp_t \ pxt_t \ rwp_t \ rwt_t)'$. We are interested in comparing the dynamics of the stock of foreign debt in the perfect and imperfect information economies. Therefore, the central variable in this analysis is the difference between the debt level in the imperfect and perfect information economies: $b_{t+1}^e = b_{t+1}^{ii} - b_{t+1}^{pi}$. Thus overborrowing corresponds to positive values of b_{t+1}^e. Because of the separation between estimation and control, the only difference between the perfect and imperfect information economies is that the decision rules are based on the actual permanent and transitory components of terms of trade and world interest rate (z_t) in the former and on their estimate $(\hat{z}_t)$ in the latter. Thus:

$$y_{t+1}^e = \Phi_1 y_t^e + \phi_2(\hat{z} - z_t) = \Phi_1 y_t^e + \Phi_2 e_t \tag{34}$$

where $y_{t+1}^e = (b_{t+1}^e \ k_{t+1}^e)'$ and e_t is a 4x1 vector of forecast errors: $(e_t^{pxp} \ e_t^{pxt} \ e_t^{rwp} \ e_t^{rwt})'$. Uncoupling y_{t+1}^e requires diagonalizing Φ_1. Define T as the diagonalizing matrix (matrix containing the eigenvectors of Φ_1) and D the diagonal form of Φ_1. To uncouple y_{t+1}^e, we simply premultiply equation (34) by T^{-1}:

$$\tilde{y}_{t+1}^e = D\tilde{y}_t^e + \tilde{\Phi}_2 e_t \Rightarrow \tilde{b}_{t+1}^e = d_1 \tilde{b}_t^e + \tilde{\Phi}_2(1,.)e_t, \quad \tilde{k}_{t+1}^e = d_2 \tilde{k}_t^e + \tilde{\Phi}_2(2,.)e_t$$

where $\tilde{y}_{t+1}^e = T^{-1} y Y_{t+1}^e$, $\tilde{\Phi}_2 = T^{-1}\Phi_2$, and d_1 and d_2 are the diagonal elements of D. Thus, $\tilde{y}_{t+1}^e$ is simply a linear transformation of the forecast error e_t. Interestingly, Proposition 1 shows that the latter follows an AR(1) process:

Proposition 1:

The forecast errors follow an AR(1) process:

$$e_t^{pxp} = (1-k_{t-1}^{pxp})e_{t-1}^{pxp} + (1-k_{t-1}^{pxp})\epsilon_t^{pxp} - k_{t-1}^{pxp}\epsilon_t^{pxt}, \qquad e_t^{pxt} = -e_t^{pxp} \tag{36}$$

$$e_t^{rwp} = (1-k_{t-1}^{rwp})e_{t-1}^{rwp} + (1-k_{t-1}^{rwp})\epsilon_t^{rwp} - k_{t-1}^{rwp}\epsilon_t^{rwt}, \qquad e_t^{rwt} = -e_t^{rwp} \tag{37}$$

where e_t^j is the forecast error for j, j=pxp, pxt, rwp, rwt; $k_{t-1}^{pxp} = s_{t-1,pxp}^2/(s_{t-1,pxp}^2 + \sigma_{pxt}^2)$, $k_{t-1}^{rwp} = s_{t-1,rwp}^2/(s_{t-1,rwp}^2 + \sigma_{rwt}^2)$, $s_{t,i}^2$ is the conditional variance of i at time t (i.e. the diagonal element of Σ_t corresponding to i), i=pxp, rwp.

Proof:

After simplification, the updating equation, equation (15), for pxp_t and pxt_t can be written as:

$$p\hat{x}p_t = p\hat{x}p_{t-1} + k_{t-1}^{pxp}((px_t - \overline{px}) - p\hat{x}p_{t-1}), \qquad p\hat{x}t_t = (px_t - \overline{px}) - p\hat{x}p_t \tag{38}$$

The corresponding conditional variances are:

$$s_{t,pxp}^2 = (s_{t-1,pxp}^2 + \sigma_{pxp}^2)[1 - \frac{s_{t-1,pxp}^2 + \sigma_{pxp}^2}{s_{t-1,pxp}^2 + \sigma_{pxp}^2 + \sigma_{pxt}^2}] \tag{39}$$

and a similar formula for $s_{t,rwp}^2$. Define the forecast errors $e_t^{pxp} = p\hat{x}p_t - pxp_t$. Using the updating equations (38), the forecast error can be rewritten as:

$$e_t^{pxp} = p\hat{x}p_{t-1} + k_{t-1}^{pxp}((px_t - \overline{px}) - p\hat{x}p_{t-1}) - pxp_t \tag{40}$$

Using the fact that $px_t = pxp_t + pxt_t + \overline{px}$, equation (40) can be rewritten as:

$$e_t^{pxp} = (p\hat{x}p_{t-1} - pxp_t) + k_{t-1}^{pxp}((pxp_t - p\hat{x}p_{t-1}) + pxt_t) \tag{41}$$

And given the fact that pxp_t is a random walk: $pxp_t = pxp_{t-1} + \epsilon_t^{pxppxt_t} + \overline{px}$, equation (41) can be simplified to:

$$e_t^{pxp} = (1-k_{t-1}^{pxp})e_{t-1}^{pxp} + k_{t-1}^{pxp}pxt_t - (1-k_{t-1}^{pxp})\epsilon_t^{pxp} \tag{42}$$

A similar formula for rwp_t holds. ∎

From equation (42) and the definition of the gain factor, k_t^{pxp}, the forecast error e_t^{pxp} converges to a random walk as the relative size of the transitory component ($\sigma_{pxt}/\sigma_{pxp}$) converges to infinity. Intuitively, when the relative size of the transitory component is very large, a change in the terms of trade is interpreted as a change in the transitory component pxt_t, which leaves the estimate of pxp_t unchanged. In the extreme case of $\sigma_{pxt}/\sigma_{pxp}=\infty$, the forecast error follows a random walk: $e_t^{pxp} = e_{t-1}^{pxp} - pxp_t$. In other words, the permanent component is entirely allocated to the forecast error as the decision maker interprets any change in the terms of trade as a transitory movement. In the other extreme case, in which the relative size of the transitory component is zero, the gain factor is one and all changes in the terms of trade are attributed to the permanent component pxp_t. Then, the forecast error is: $e_t^{pxp} = pxt_t$. Consequently, the forecast error is simply the transitory component pxt_t which is white noise. For the intermediate cases the forecast error follows a stationary AR(1) process.

Since b_{t+1}^e is simply a linear transformation of e_t, it inherits all the properties of e_t. Proposition 1 establishes that the forecast error e_t is an AR(1) process and is therefore autocorrelated. This implies that uncertainty concerning the longevity of a shock may lead to persistent *overborrowing* and therefore contribute_to debt accumulation. When the size of the transitory component is relatively large, and consequently when shocks are highly unpredictable, the forecast error becomes more persistent, resulting in persistent overborrowing and making debt accumulation likely.

Table 3 gives a quantitative assessment of the deviations from the optimal borrowing behavior, as measured by b_{t+1}^e/GDP_t.[20] For the case of a steady-state debt level of 1 percent of GDP, a permanent decline in the terms of trade of 10 percent will generate an overborrowing effect between 0.04 percent and .36 percent of GDP (depending on the relative size of the permanent component q) during the first two periods after the shock. The total cumulative effect is relatively small: 1.74 percent of GDP for q = 0.1 and 0.06 percent for q = 10. It is even smaller for a temporary 10 percent improvement in the terms of trade; the cumulative effect is only 0.71 percent. Note that the total cumulative effect depends on the relative size of the permanent component in the case of a permanent shock but not for a transitory shock. The reason is that the estimates of pxp and pxt converge to their true value in the case of a transitory shock but not in the case of permanent shock. For a permanent shock, the forecast error inherits the unit root of the permanent component.

A permanent decline of 10 percent in the world interest rate generates a cumulative overborrowing effect of 1.26 percent, while a transitory increase of 10 percent leads to an overborrowing effect of 0.56 percent. Thus when the economy starts with a low debt, debt accumulation because of imperfect information is relatively small.[21] As the next three panels show, however, if the economy starts with a significant debt level, overborrowing from imperfect

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[20]The stock of foreign debt in the perfect information economy is referred to as the optimal debt level, even though the stock of foreign debt in the imperfect information economy is also optimal under that information structure.

[21]*Starting* debt level means *steady-state* debt level since the economy is simulated around the steady state.

information may be substantial. For example, with an initial debt level of 25 percent of GDP, a permanent decline in the terms of trade of 10 percent can generate excessive debt as much as 28.37 percent of GDP. As a reference, the median of the q estimates in the data is 0.35 for terms of trade and 0.23 for the interest rate. Thus the model predicts an overborrowing effect between 10.51 percent and 28.37 percent of GDP in the case of a permanent decline in terms of trade of 10 percent. The effect is even stronger in the case of a permanent decline in the world interest rate (between 19.66 percent and 44.30 percent). These effects increase substantially with the initial debt level. Note that for low debt levels, overborrowing effects from terms of trade dominate. This order is reversed as the initial debt level rises which increases wealth effects from interest rate fluctuations.

V. CONCLUSIONS

This paper analyzes the borrowing behavior of a small open economy that relies heavily on imports for its capital formation and faces an upward-sloping supply function of foreign loans, in an environment where decision-makers face uncertainty about the longevity of external shocks. The model replicates fairly well the business cycle properties of developing countries' data.

It is shown that uncertainty concerning the longevity of shocks generates forecast errors that are autocorrelated even when decion makers use rationally all the information available. These autocorrelated forecast errors can generate substantial debt accumulation. In particular, decion makers tend to over borrow during periods of negative, permanent external shocks (permanent declines in the terms of trade and permanent increases in the world interest rate) and during periods of positive transitory external shocks, even under the *rationality* paradigm. Furthermore, this overborrowing behavior can be relatively persistent, generating debt accumulation especially if shocks are highly unpredictable. This finding supports the view that the short-lived commodity booms of the 1970s may have done more harm than good by encouraging some developing countries to over borrow, contributing to their debt accumulation and, hence, increased their vulnerability to the exceptionally high interest rates of the early 1980s.

Figure 1: Impulse Response to Permanent and Transitory Shocks (percent)

1. Permanent increase of 1% in the terms of trade
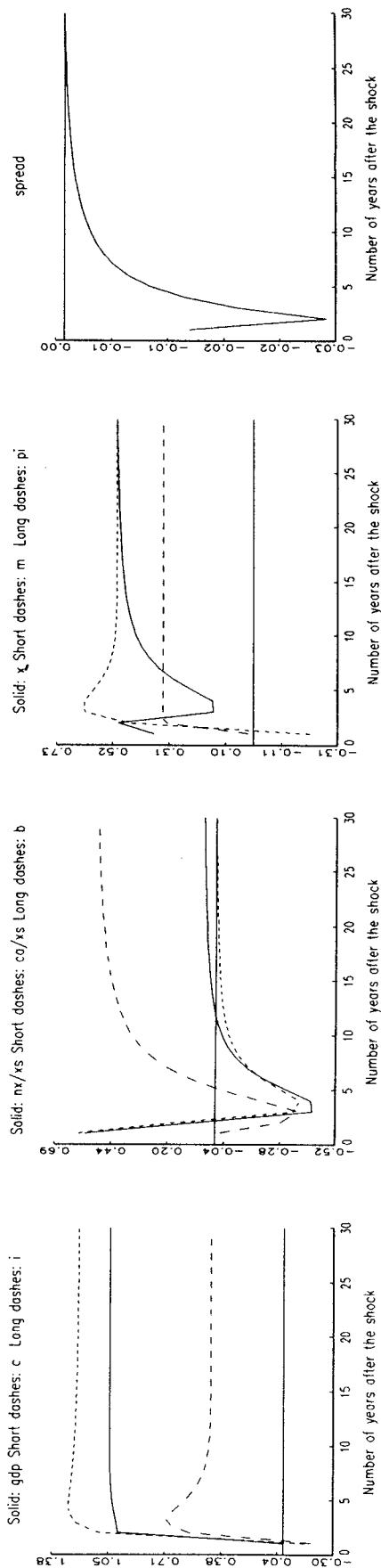
2. Transitory increase of 1% in the terms of trade
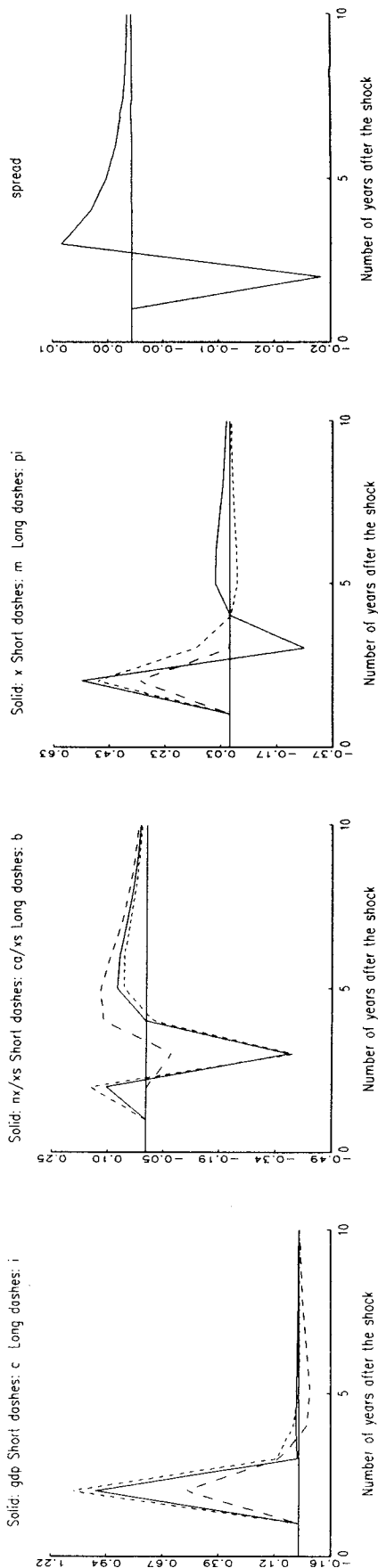
c:	Consumption	nx:	Net exports	pi:	Investment price
i:	Investment	m:	Imports		
x:	Exports	ca:	Current account		
xs:	Steady-state exports	b:	Foreign debt		

3. Permanent increase of 1% in the world interest rate
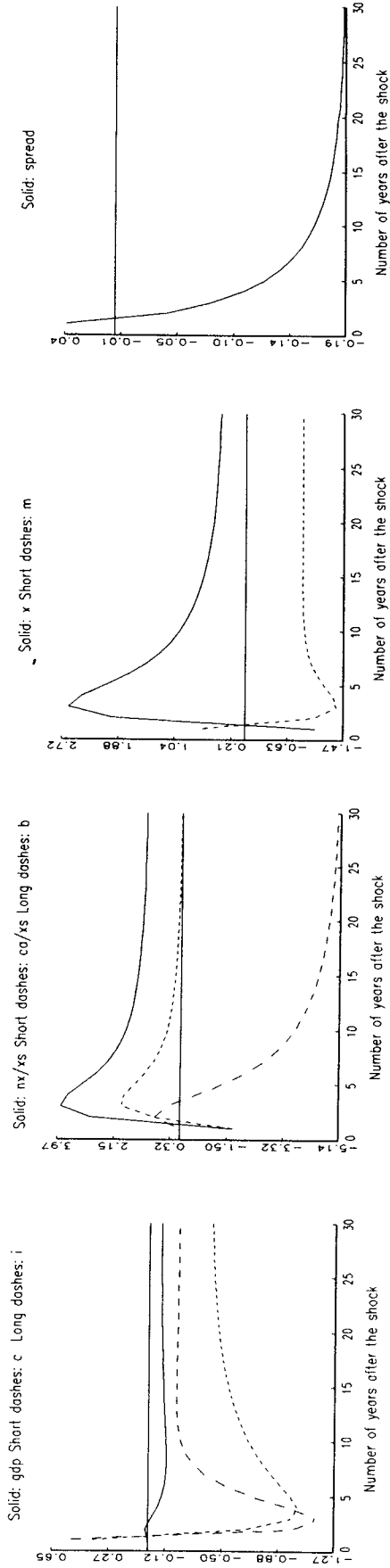
4. Transitory increase of 1% in the world interest rate
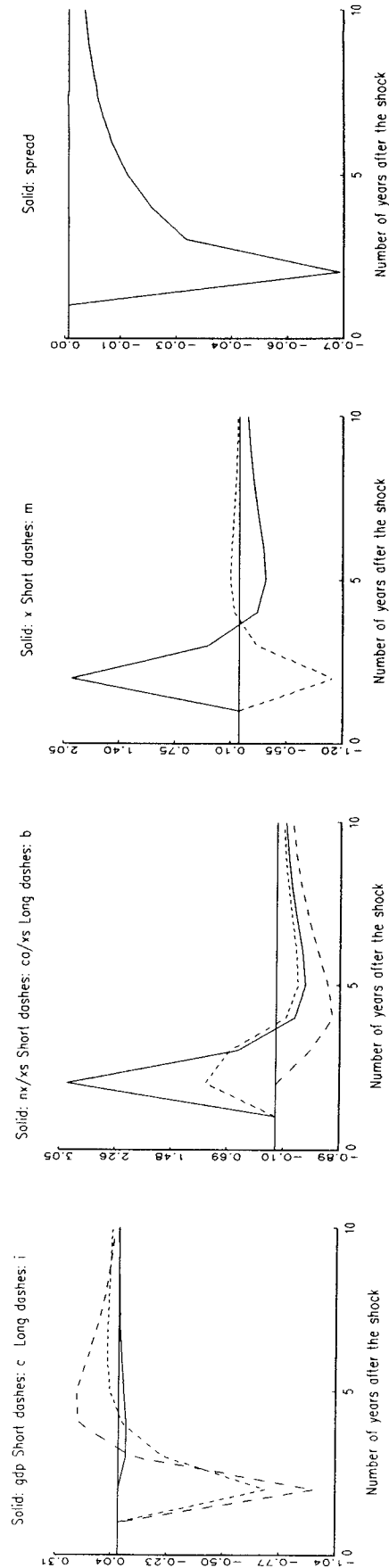
c:	Consumption	
i:	Investment	
x:	Exports	
xs:	Steady-state exports	
m:	Imports	

nx:	Net exports	
ca:	Current account	
b:	Foreign debt	
pi:	Investment price	

Figure 2: Impulse Response to an Increase of 1 % in Productivity

c: Consumption
i: Investment
x: Exports
xs: Steady-state exports
m: Imports

nx: Net exports
ca: Current account
b: Foreign debt
pi: Investment price
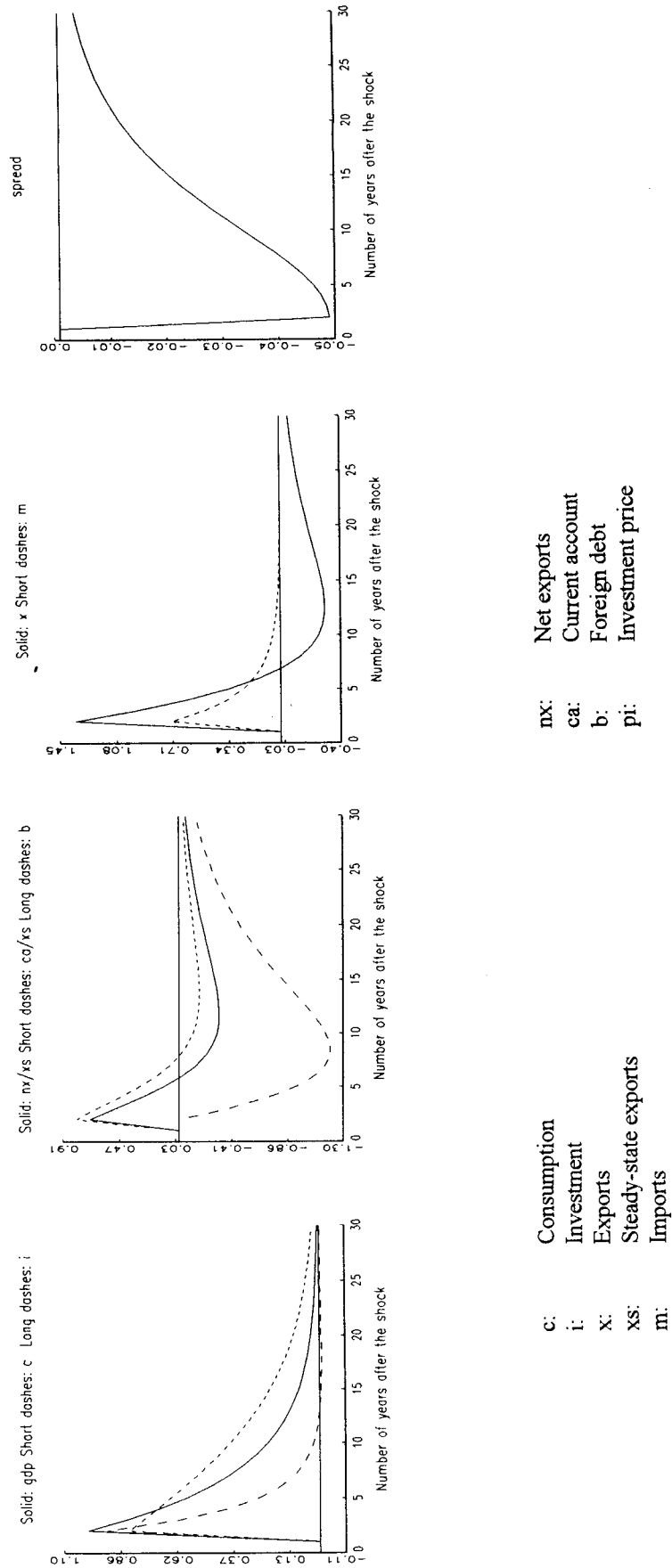
Table 1: Relative size of the permanent and transitory components of the terms of trade and the world interest rate

	px	rw
1 Bangladesh	0.1968	-
2 Brazil	0.3733	-
3 Cote d'Ivoire	0.4466	-
4 Dominican Republic	0.2312	0.1954
5 Ecuador		0.1284
6 Guyana	0.4581	0.1028
7 Hong Kong	0.7096	-
8 India	0.4769	0.5486
9 Israel	0.4204	-
10 Jamaica	0.4550	0.2577
11 Korea, Republic of	0.2750	0.2991
12 Malawi	0.1381	0.1348
13 Malta	0.1342	-
14 Mauritius	-	0.1167
15 Niger	0.0404	-
16 Peru	0.0618	-
17 Portugal	-	0.2375
18 Senegal	0.2637	0.3028
19 Sri Lanka	0.3244	-
20 Togo	0.5051	-
21 Tunisia	-	0.2319
22 Turkey	0.4220	-
Mean	0.3296	0.2323
Median	0.3489	0.2319
Std	0.1710	0.1213
Min	0.0404	0.1028
Max	0.7096	0.5486

Note: The following unobserved-components model has been estimated for both terms of trade (px defined as the ratio of the export price to the import price of goods and nonfactor services) and the world real interest rate (rw defined as the LIBOR minus the growth rate of the import price of goods and nonfactor services): $y_t = x_t + \varepsilon_t^T$ and $x_t = x_{t-1} + \varepsilon_t^P$; $E(\varepsilon_s^T . \varepsilon_t^P) = 0$ for all s,t; x_t and ε_t^T are respectively the permanent and transitory components; $E(\varepsilon_t^T)^2 = \sigma_T^2$ and $E(\varepsilon_t^P)^2 = \sigma_P^2$. The relative size of the permanent and transitory components is given by $q = \sigma_P/\sigma_T$. The samples are 1960-93 for px and 1970-93 for rw.

Table 2. Business cycle properties of the data and model

DATA	Relative volatility c	i	x	m	nx	ca	debt	px	r	Comovement c	i	x	m	nx	ca	debt	px	r	Autocorrelation gdp	debt	r
1 Bangladesh	3.91	1.47	0.97	0.96	1.87	3.85	1.55	1.01	-	0.18	0.66	0.60	0.72	-0.12	0.15	0.29	0.60	-	0.08	0.33	7.54
2 Brazil	8.84	1.39	0.74	1.01	1.07	7.18	1.13	0.63	0.70	0.42	0.90	0.15	0.48	-0.31	0.07	0.55	0.45	0.50	0.26	0.22	6.54
3 Cote d'Ivoire	1.35	0.97	0.46	0.31	0.46	5.69	1.32	0.61	1.15	0.44	0.74	0.22	0.33	-0.04	-0.64	0.91	0.19	0.69	0.57	0.69	5.49
4 Dominican Republic	1.07	1.07	0.53	0.51	0.33	2.56	1.11	0.49	0.69	0.32	0.82	0.59	0.47	0.32	-0.65	0.95	0.19	0.46	0.39	0.60	6.56
5 Ecuador	1.81	2.33	2.39	2.36	1.51	4.85	3.71	1.25	1.34	0.33	0.67	0.42	0.34	0.14	-0.08	0.39	0.48	-0.37	0.77	0.74	1.53
6 Guyana	4.77	4.10	1.73	1.60	0.81	6.10	2.41	0.72	0.54	0.26	0.34	0.24	0.23	0.08	-0.49	0.46	0.26	-0.85	0.29	0.53	-
7 Hong Kong	7.85	7.62	3.13	1.65	2.32	3.81	-	0.41	-	0.13	0.21	0.24	0.52	-0.06	-0.40	-	0.10	-	0.43	-	-
8 India	4.87	3.36	1.85	1.63	0.62	2.86	1.11	1.51	-	0.73	0.81	0.88	0.90	0.34	-0.06	0.95	0.89	-	0.44	0.41	-
9 Israel	1.28	0.81	0.75	0.80	0.18	1.61	-	0.18	0.51	0.54	0.87	0.88	0.90	-0.48	0.17	-	0.77	-	0.61	-	8.64
10 Jamaica	2.76	4.26	0.67	0.53	0.59	1.16	1.25	0.98	0.51	0.23	0.16	0.40	0.30	0.18	0.21	0.12	0.26	-0.80	0.43	0.66	5.65
11 Korea, Republic of	1.79	0.75	0.73	0.73	0.14	8.23	0.54	0.15	0.68	0.47	0.83	0.83	0.84	-0.10	0.26	0.58	-0.40	0.08	0.58	0.45	2.52
12 Malawi	1.14	0.69	0.98	0.86	0.33	2.99	0.61	0.34	1.84	0.07	0.26	0.88	0.87	0.42	-0.02	0.66	-0.55	-0.50	0.63	0.52	-
13 Malta	2.62	2.70	1.03	1.12	0.46	0.57	0.85	0.82	-	0.14	0.12	0.90	0.95	-0.37	0.13	0.89	-0.28	-	0.40	0.31	6.58
14 Mauritania	0.78	0.88	0.18	0.19	0.24	0.37	0.67	0.20	0.93	0.49	0.46	0.31	0.08	0.21	0.02	0.32	0.06	-0.76	0.47	0.43	1.55
15 Mauritius	1.35	0.89	0.62	0.62	0.09	2.74	0.57	0.15	0.99	0.42	0.72	0.80	0.80	-0.01	-0.01	0.82	0.55	-0.22	0.64	0.58	7.52
16 Mexico	1.37	0.98	0.52	0.57	0.16	-	0.52	0.16	1.04	0.51	0.85	0.75	0.72	-0.14	-	0.24	0.69	-0.16	0.41	0.51	5.52
17 Morocco	1.56	1.06	0.93	0.85	0.33	-	0.65	0.31	1.13	0.54	0.73	0.81	0.82	0.23	0.72	0.72	0.77	-0.28	0.41	0.18	5.55
18 Niger	1.66	1.25	0.74	0.76	0.30	3.58	0.67	0.25	1.19	0.40	0.61	0.86	0.90	-0.22	0.01	0.80	0.11	-0.72	0.58	0.44	3.50
19 Pakistan	1.59	0.83	0.75	0.67	0.28	6.32	0.63	0.33	1.50	0.59	0.83	0.77	0.79	0.35	-0.17	0.69	0.69	0.27	0.34	0.25	7.39
20 Peru	2.62	3.16	0.47	0.41	0.64	2.00	0.84	0.40	1.07	0.27	0.30	0.01	0.45	-0.34	-0.16	0.67	0.21	-0.50	0.46	0.62	6.58
21 Philippines	0.79	0.80	0.20	0.12	0.21	-	0.95	0.18	1.18	0.75	0.81	0.19	0.03	0.19	-	0.68	0.32	-0.57	0.54	0.48	5.45
22 Portugal	1.40	0.90	0.96	0.96	0.13	7.04	0.71	0.14	1.03	0.73	0.99	0.94	0.95	-0.17	0.07	0.96	0.04	-0.08	0.53	0.42	-
23 Rwanda	1.91	2.20	1.43	1.26	0.74	3.94	1.31	0.49	-	0.77	0.77	0.32	0.40	-0.05	-0.17	0.89	-0.34	-	0.50	0.51	4.29
24 Senegal	1.10	1.21	0.65	0.61	0.19	5.25	0.88	0.15	0.63	0.72	0.63	0.46	0.51	-0.12	-0.31	0.86	-0.23	0.68	0.37	0.41	-
25 Singapore	1.56	0.98	0.99	0.99	0.01	1.70	-	0.07	-	0.94	1.00	1.00	1.00	-0.05	-0.40	-	-0.56	-	0.47	-	2.61
26 Sri Lanka	2.17	1.08	1.34	1.11	0.58	1.53	1.21	0.86	0.66	0.57	0.65	0.82	0.83	0.39	0.31	0.89	0.53	-0.71	0.44	0.59	4.46
27 Sudan	0.81	0.79	0.72	0.68	0.30	2.74	0.68	0.20	1.11	0.84	0.79	0.61	0.64	0.06	-0.59	0.82	-0.07	-0.31	0.51	0.50	6.48
28 Thailand	1.18	0.93	0.93	0.93	0.06	2.35	0.70	0.17	0.29	0.79	0.74	0.81	0.80	0.18	-0.32	0.92	0.71	0.11	0.53	0.42	0.72
29 Togo	1.63	1.24	0.91	0.81	0.46	1.80	1.30	0.83	0.35	0.61	0.42	0.61	0.65	-0.02	0.64	0.72	0.34	-0.45	0.16	0.70	4.55
30 Tunisia	1.18	0.87	0.54	0.63	0.18	2.16	0.66	0.33	0.72	0.39	0.25	0.62	0.58	-0.12	-0.07	0.78	0.44	-0.13	0.51	0.43	4.54
31 Turkey	1.24	1.25	0.80	0.87	0.26	1.50	0.93	0.30	0.48	0.79	0.83	0.73	0.78	-0.37	-0.36	0.97	0.15	-0.18	0.39	0.54	7.21
32 Uruguay	1.09	1.11	0.71	0.67	0.20	4.14	0.90	0.35	0.23	0.52	0.78	0.61	0.66	-0.02	-0.35	0.78	-0.20	0.17	0.61	0.35	3.65
33 Venezuela	1.29	1.06	1.07	1.08	0.28	4.30	0.65	0.29	3.51	0.75	0.74	0.85	0.85	-0.06	0.15	0.47	-0.15	-0.41	0.61	0.51	5.85
34 Zaire	1.24	1.31	0.74	0.73	0.54	0.52	0.66	0.73	1.34	0.30	0.50	0.41	0.65	-0.31	-0.53	0.65	-0.37	-0.72	0.34	0.14	6.97
35 Zambia	1.07	0.92	0.60	0.44	0.30	0.66	0.69	0.42	0.51	0.47	0.18	0.28	0.36	0.04	-0.35	0.49	0.50	-0.17	0.37	0.29	-
Mean	2.13	1.63	0.94	0.86	0.49	3.32	1.01	0.47	0.98	0.50	0.63	0.59	0.63	-0.01	-0.12	0.68	0.20	-0.21	0.46	0.46	5.19
median	1.40	1.07	0.75	0.80	0.30	2.80	0.85	0.34	0.96	0.49	0.73	0.61	0.66	-0.04	-0.08	0.72	0.21	-0.25	0.46	0.47	5.54
Std	1.82	1.39	0.58	0.44	0.50	2.09	0.62	0.34	0.62	0.22	0.25	0.27	0.25	0.23	0.30	0.23	0.40	0.44	0.13	0.15	2.01
Min	0.78	0.69	0.18	0.12	0.01	0.37	0.52	0.07	0.23	0.07	0.12	0.01	0.03	-0.48	-0.65	0.12	-0.56	-0.85	0.08	0.14	0.72
Max	8.84	7.62	3.13	2.36	2.32	8.23	3.71	1.51	3.51	0.94	1.00	1.00	1.00	0.42	0.64	0.97	0.89	0.69	0.77	0.74	8.64
MODEL	1.06 (0.11)	1.28 (0.15)	1.73 (0.15)	1.14 (0.20)	2.26 (0.45)	1.11 (0.33)	0.94 (0.25)	0.20 (0.03)	0.69 (0.12)	0.89 (0.03)	0.80 (0.07)	0.61 (0.14)	0.75 (0.06)	-0.20 (0.18)	-0.49 (0.18)	0.11 (0.22)	0.13 (0.19)	-0.10 (0.15)	0.35 (0.17)	0.73 (0.12)	

Note: Statistics are based on detrended (by H-P filter, λ=100) series. Variables are private consumption (c), gross domestic investment (i), exports (x), imports (m), net exports (nx), current account (ca), external debt (debt), terms of trade (px), and the real interest rate on total debt (r). All variables are in logs except r, nx, and ca. nx is defined as exports minus imports divided by exports with all three variables in nominal terms. ca is the World Bank's official statistic divided by exports in nominal terms. All variables are expressed in terms of importables both in the data and in the model. *Relative volatility* is defined as the relative standard deviation of each variable to gdp. *Comovement* is defined as the correlation of each variable with gdp. In the model these statistics are the sample means of statistics computed for each of 100 simulations. Each simulation consists of 34 observations, which is the sample size of the data. The numbers in parentheses are sample standard deviations of these statistics. The last column gives the average (over 1970-93) real interest rate on total debt.

Table 3: The difference between debt/GDP in imperfect and perfect information economies (percent)

Steady-state debt/gdp=.01

Decrease of 10% in pxp

k	2	5	10	20	inf
q					
0.1	0.36	1.08	1.54	1.72	1.74
0.5	0.25	0.53	0.62	0.64	0.65
1	0.19	0.35	0.38	0.40	0.40
2	0.13	0.21	0.23	0.24	0.24
5	0.07	0.10	0.11	0.11	0.11
10	0.04	0.05	0.06	0.06	0.06

Increase of 10% in pxt

k	2	5	10	20	inf
0.1	0.15	0.44	0.63	0.70	0.71
0.5	0.27	0.59	0.68	0.71	0.71
1	0.34	0.62	0.68	0.71	0.71
2	0.40	0.63	0.68	0.71	0.71
5	0.47	0.64	0.69	0.71	0.71
10	0.50	0.64	0.69	0.71	0.71

Increase of 10% in rwp

k	2	5	10	20	inf
0.1	0.36	0.95	1.20	1.25	1.26
0.5	0.26	0.51	0.55	0.56	0.56
1	0.22	0.40	0.42	0.42	0.42
2	0.20	0.33	0.34	0.34	0.35
5	0.18	0.29	0.29	0.29	0.29
10	0.17	0.27	0.27	0.27	0.27

Decrease of 10% in rwt

k	2	5	10	20	inf
0.1	0.16	0.42	0.53	0.56	0.56
0.5	0.26	0.51	0.55	0.56	0.56
1	0.29	0.53	0.55	0.56	0.56
2	0.32	0.54	0.55	0.56	0.56
5	0.34	0.54	0.55	0.56	0.56
10	0.34	0.54	0.55	0.56	0.56

Steady-state debt/gdp=.25

Decrease of 10% in pxp

k	2	5	10	20	inf
q					
0.1	2.62	12.59	22.29	27.46	28.37
0.5	1.79	6.55	9.26	10.32	10.51
1	1.37	4.37	5.81	6.39	6.49
2	0.96	2.71	3.47	3.79	3.85
5	0.52	1.30	1.63	1.77	1.80
10	0.30	0.70	0.87	0.95	0.96

Increase of 10% in pxt

k	2	5	10	20	inf
0.1	1.07	5.13	9.10	11.22	11.59
0.5	1.98	7.22	10.21	11.38	11.59
1	2.44	7.80	10.36	11.40	11.59
2	2.89	8.15	10.44	11.41	11.59
5	3.38	8.39	10.49	11.42	11.59
10	3.62	8.47	10.51	11.42	11.59

Increase of 10% in rwp

k	2	5	10	20	inf
0.1	4.83	22.00	36.63	43.24	44.30
0.5	3.49	12.62	17.55	19.35	19.66
1	3.01	10.06	13.44	14.69	14.91
2	2.67	8.42	11.00	11.98	12.16
5	2.41	7.28	9.37	10.18	10.32
10	2.30	6.86	8.78	9.54	9.67

Decrease of 10% in rwt

k	2	5	10	20	inf
0.1	2.13	9.67	16.12	19.07	19.54
0.5	3.46	12.50	17.41	19.23	19.55
1	3.94	13.13	17.58	19.25	19.55
2	4.28	13.49	17.66	19.26	19.55
5	4.55	13.73	17.71	19.27	19.55
10	4.65	13.81	17.72	19.27	19.55

Steady-state debt/gdp=.50

Decrease of 10% in pxp

k	2	5	10	20	inf
q					
0.1	2.92	16.31	33.39	46.11	49.81
0.5	2.00	8.64	14.24	17.52	18.45
1	1.53	5.82	9.00	10.87	11.40
2	1.07	3.63	5.40	6.45	6.75
5	0.58	1.76	2.54	3.01	3.15
10	0.34	0.96	1.37	1.62	1.69

Increase of 10% in pxt

k	2	5	10	20	inf
0.1	1.19	6.65	13.63	18.84	20.35
0.5	2.21	9.52	15.70	19.33	20.35
1	2.73	10.38	16.06	19.40	20.35
2	3.23	10.94	16.26	19.44	20.35
5	3.77	11.34	16.40	19.47	20.35
10	4.04	11.50	16.45	19.48	20.35

Increase of 10% in rwp

k	2	5	10	20	inf
0.1	7.35	39.62	77.89	104.16	111.51
0.5	5.31	23.13	38.23	47.02	49.49
1	4.59	18.54	29.42	35.74	37.54
2	4.06	15.59	24.17	29.17	30.59
5	3.66	13.51	20.62	24.79	25.98
10	3.51	12.75	19.35	23.23	24.34

Decrease of 10% in rwt

k	2	5	10	20	inf
0.1	3.24	17.39	34.15	45.74	49.01
0.5	5.27	22.85	37.77	46.54	49.02
1	6.00	24.15	38.33	46.66	49.02
2	6.52	24.91	38.63	46.72	49.03
5	6.92	25.42	38.82	46.76	49.03
10	7.07	25.60	38.89	46.77	49.03

Steady-state debt/gdp=1

Decrease of 10% in pxp

k	2	5	10	20	inf
q					
0.1	3.04	19.18	45.70	75.15	93.60
0.5	2.08	10.31	20.03	29.13	34.66
1	1.59	6.99	12.77	18.14	21.42
2	1.12	4.39	7.70	10.80	12.69
5	0.61	2.14	3.64	5.06	5.92
10	0.35	1.17	1.96	2.72	3.17

Increase of 10% in pxt

k	2	5	10	20	inf
0.1	1.24	7.82	18.65	30.70	38.24
0.5	2.29	11.36	22.09	32.14	38.24
1	2.83	12.46	22.78	32.39	38.24
2	3.36	13.22	23.21	32.54	38.24
5	3.92	13.79	23.52	32.66	38.24
10	4.20	14.02	23.64	32.70	38.24

Increase of 10% in rwp

k	2	5	10	20	inf
0.1	10.97	67.35	155.93	249.94	307.55
0.5	7.93	39.84	78.35	114.58	136.52
1	6.85	32.07	60.65	87.34	103.53
2	6.07	27.06	49.99	71.39	84.39
5	5.47	23.50	42.75	60.73	71.65
10	5.24	22.19	40.16	56.94	67.14

Decrease of 10% in rwt

k	2	5	10	20	inf
0.1	4.83	29.57	68.17	109.16	134.42
0.5	7.87	39.35	77.12	112.76	134.43
1	8.95	41.75	78.71	113.34	134.44
2	9.73	43.21	79.60	113.66	134.44
5	10.33	44.19	80.17	113.87	134.44
10	10.56	44.54	80.37	113.95	134.44

Note: The figures are cumulative effects over k periods after the shock. The table is divided into 4 panels corresponding to different steady-state debt levels. Each panel is divided in four sub-panels corresponding respectively to a 10% increase in the permanent component of terms of trade (*pxp*), a 10% decline in the transitory component of terms of trade (*pxt*), a decrease of 10% in the permanent component of the world interest rate (*rwp*), and a 10% increase in the transitory component of the world interest rate (*rwt*). The column q gives the ratio of the standard deviation of the innovation of the permanent and transitory components.