Debt Denomination and Default Risk in Emerging Markets

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Abstract

The inability of emerging market economies to borrow in domestic currency in international financial markets often leaves them vulnerable to fluctuations in the real exchange rate. In these countries, real exchange rate depreciations are associated with declines in output, which increase the cost of foreign currency debt exactly when the repayment capacity is low, thereby hindering debt service. This paper develops a two-sector small open economy model to analyze the effect of debt denomination on default risk and interest rates in emerging markets. Default risk is determined endogenously and depends on the incentives for repayment. The economy can borrow using bonds denominated in tradable or nontradable goods, which are used as proxies for foreign currency and domestic currency debt respectively. The model predicts, in line with empirical evidence, that tradable denominated debt increases the default risk and leads to higher interest rates. As a result, the amount of debt that can be sustained by the economy increases with an increase in nontradable-indexed borrowing. In addition, this type of debt is shown to reduce the default rate and interest rate volatility and increase the welfare.

JEL Classification: E44, F32, F34

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1 Introduction

The inability to borrow in domestic currency in international financial markets is a widespread phenomenon among emerging market economies[1]. The problems associated with foreign currency borrowing have become apparent after the recent emerging market crises and have been the subject of a vast literature. This issue has been analyzed as a factor leading to currency crises, as well as affecting the policy options of governments in responding to crises. Another aspect of foreign currency borrrowing, which received more attention after the Argentine crisis, is its effect on sovereign default risk. In many papers and policy discussions, large amounts of foreign currency debt has been pointed out as one of the factors leading to default in Argentina[2]. It has also been documented by Eichengreen, Hausmann and Panizza (2003a, 2003b) that, credit ratings deteriorate as the share of foreign currency debt increases, reflecting a higher sovereign default risk.

The reason for debt denomination to affect the default risk is that real exchange rate fluctuations become relevant for repayment capacity when debt is denominated in foreign currency. The reason for this to cause a problem in developing countries is the co-movement of output and real exchange rates. In these countries real exchange rate depreciations are associated with output declines, increasing the value of foreign currency denominated debt exactly when the country's repayment ability has deteriorated[3]. Therefore, with a high share of foreign currency debt, debt service becomes even harder during low output episodes.

This paper analyzes how having to borrow in foreign currency affects default incentives and the interest rate behavior of emerging market economies. In order to study the rela-

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[1] Table A1 in the appendix shows foreign currency debt as a share of total international debt for select country groups. In developing countries, the average share of foreign currency debt is about 2.5% for the period 1993-2001.

[2] See Hausmann and Velasco (2002), Feldstein (2002), Calvo, Izquierdo and Talvi (2003), Perry and Serven (2003).

[3] Figure A2 in the appendix plots real exchange rate and output in different emerging market economies. Both series are HP filtered.

tionships between default risk, debt denomination and real exchange rate fluctuations, a stochastic small open economy model with endogenous default risk and equilibrium default is considered. The paper is based on Eaton and Gersovitz (1981) and Arellano (2005) in its modeling of endogenous default risk. The borrowing country has the option of defaulting on its debt, in which case it will be temporarily excluded from international borrowing and lending, and lose a share of its output. Interest rates, then, are determined endogenously as a function of the default probability of the economy. A real model is considered with two goods, tradables and nontradables, where the endowments of both goods are stochastic. The economy can borrow using either bonds denominated in tradable goods (analogous to foreign currency debt) or bonds whose return is indexed to the relative price of the nontradable good (analogous to domestic currency debt). The price of nontradables is determined by the stochastic shocks to tradable and nontradable endowments. In the data, the correlation between real exchange rates and output in developing countries is such that output declines are associated with depreciation of the real exchange rate. For the type of shocks that generate this correlation between real exchange rates and output, I show that indexing the value of foreign liabilities to the price of nontradables reduces default risk. Since the nontradable price is high during good times and low during bad times, the repayment value of nontradable denominated debt moves in the same direction as output, which improves international risk sharing and reduces default incentives.

Modeling of foreign and domestic currency debt as bonds indexed to the tradable and nontradable goods captures the change in the relative value of debt denominated in different currencies. What makes foreign currency debt harder to repay is an increase in its value relative to the real value of the country's output through a real depreciation. In the model, a real exchange rate depreciation reduces the value of nontradable indexed debt while the value of tradable indexed debt is constant. Therefore, tradable indexed debt becomes relatively more costly with a real depreciation just as foreign currency debt becomes more costly compared with domestic currency debt. This kind of a formulation has been used by

other papers like Schneider and Tornell (2000) and Chamon (2002), while Krugman (1999) and Caballero and Krishnamurthy (2003) also use real models where they model foreign and domestic currency debt as borrowing with bonds denominated in domestic and foreign goods.

The model is solved quantitatively using data from the Argentine economy. The results show that default incentives, and hence interest rates, increase as the share of tradable denominated debt increases. Therefore, the model predicts that the default risk is higher when debt is denominated in foreign currency, in line with the empirical evidence. The results also show important differences for the volatility of interest rates and the default rate as well as the correlation of output and interest rates between the cases of tradable and nontradable denominated debt. Borrowing with nontradable denominated bonds reduces the volatility of interest rates and the default rate of the country as this type of borrowing provides better insurance against low output states. It also leads to a higher level of welfare since a smoother consumption profile can be achieved due to the fact that repayment on nontradable indexed debt decreases in bad times and increases in good times. The model matches the countercyclicality of interest rates when debt is denominated in tradable units, which is in line with the increase in interest rates observed during low output episodes in emerging market economies. However, this prediction changes when debt is indexed to the nontradable price, in which case interest rates become procyclical.

This paper is the first to theoretically analyze the effects of currency denomination of debt in the context of sovereign default risk, although other aspects of debt denomination have received considerable attention in the literature.

One strand of the literature has analyzed the effects of foreign currency debt on the occurrence of currency crises and on the optimal monetary and exchange rate policy. The emphasis in this set of papers is on the balance sheet effects of a currency depreciation when firms are credit constrained, in the sense that the amount that can be borrowed depends on the net worth of the firm. With debt denominated in foreign currency, a depreciation

has contractionary effects through a reduction in net worth. This, in turn, reduces the amount that can be borrowed and constrains investment. Therefore, the effects of a bad shock are amplified, and this may lead to multiple equilibria where changes in expectations trigger a crisis. The role of foreign currency debt in financial crises through such a channel has been studied by papers such as Krugman (1999) and Aghion, Bacchetta and Banerjee (2001a, 2001b). Another aspect of the same channel is that foreign currency debt affects the policy response to crises. The conventional policy prescription in responding to an adverse shock has been to engage in expansionary monetary policy. This, however, increases the repayment problems of firms and banks in the presence of foreign currency debt by leading to a depreciation of the currency. This line of reasoning has been used by Aghion, Bacchetta and Banerjee (2000, 2001a), Bacchetta (2000) and Cespedes, Chang and Velasco (2000, 2002) in analyzing optimal monetary and exchange rate policy in the presence of foreign currency debt. In this paper, I analyze foreign currency debt in relation to sovereign default risk rather than currency crises, and in this setup, foreign currency debt directly affects the default incentives of the government without resorting to the balance sheet channel.

Another strand of literature has developed around studying the reasons for the inability of developing countries to borrow in their domestic currency. In the case of public debt, this has been explained by the government's incentives to create inflation and erode the value of debt when it is time to repay (Calvo and Guidotti, 1990). In the case of private borrowing, explanations offered are bailout guarantees (Schneider and Tornell, 2000; Burnside, Eichenbaum and Rebelo, 2000), lack of domestic financial development (Caballero and Krishnamurthy, 2003), expectations of a large monetary expansion associated with a risky monetary environment (Jeanne, 2002) and the correlation of default risk with real depreciations and inability to enforce creditor seniority in foreign debt contracts (Chamon, 2002). This paper, however, will take the inability of developing countries to borrow in their domestic currency as given and analyze how it affects the default risk and interest rate behavior of these countries.

In terms of the model used, the paper is related to Arellano (2005), Aguiar and Gopinath (2003a), Yue (2005) and Sapriza and Cuadra (2005). Each of these papers models default risk endogenously as dependent on the incentives for repayment, and studies the implications of such a model in terms of default risk, interest rates and business cycle properties. In all of these studies, borrowing is done with bonds that pay one unit of output regardless of the state of the economy, which is the same as the tradable denominated bonds in my model[4]. Therefore, the implicit assumption in these papers is that the value of the amount to be repaid moves with value of the tradable good as in foreign currency borrowing. The distinguishing feature of my paper is to introduce another bond that is indexed to the nontradable price, which allows the analysis of debt denomination in the context of sovereign default, and investigate how the implications of the model changes.

The paper is organized as follows: Section 2 presents the model, section 3 presents the numerical solution of the model with the calibration of the data and the results. Sensitivity analysis is presented in section 4 and section 5 concludes.

2   The Model

I analyze a small open economy model with two sectors, a tradable sector and a nontradable sector. There is a benevolent government whose objective is to maximize the households' utility. The government taxes the nontradable endowment of the households and provides a public good with the proceeds. It can also borrow in international financial markets to smooth the households' consumption of the public good. Debt contracts are not enforceable as the government has the option to default. When the government defaults, it is temporarily excluded from international financial markets and the aggregate endowment

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[4]In Aguiar and Gopinath (2003a) and Yue (2005) there is only one good which is tradable. In Arellano (2005) there are two goods, tradable and nontradable, and each unit of bond repays one unit of the tradable good. Sapriza and Cuadra (2005) also has two goods, importable and exportable, and each unit of bond repays one unit of the importable good.

is reduced. The foreign lenders charge a premium on lending based on the expected default probability of the government. Borrowing can be done using two types of bonds: a tradable denominated bond (T-bond) which delivers one unit of tradable good next period and a nontradable denominated bond (N-bond) which delivers an amount of tradable good equivalent to one unit of nontradable good. In the case of a default, I assume that the government defaults fully and on both types of debt.

2.1 Households

Households are infinitely lived and have preferences over consumption of tradable, nontradable, and publicly provided consumption goods:

$$E_0 \sum_{t=0}^{\infty} \beta^t U(c(c_t^T, c_t^N), g_t) \tag{1}$$

where $0 < \beta < 1$ is the discount factor; c_t^T and c_t^N are respectively consumption of the tradable and nontradable goods; $c(.)$ is the constant elasticity of substitution aggregator; and g_t is the consumption of the public good. The period utility function $U(.)$ is assumed to be increasing, strictly concave and twice continuously differentiable. In each period households receive stochastic endowment streams of tradable and nontradable goods, y_t^T and y_t^N. The state vector of endowment shocks is defined as $s_t = (y_t^T, y_t^N) \in Y$. Shocks are assumed to follow a Markov process with an exogenous transition probability function $\pi(s_{t+1} | s_t)$.

The budget constraint of the household is as follows:

$$c_t^T + P_t^N c_t^N = y_t^T + P_t^N y_t^N - \tau P_t^N y_t^N \tag{2}$$

where τ is the tax levied on the nontradable endowment. Households receive a transfer of the public good, g_t, that is distributed as a lump sum by the government.

P^N is the relative price of the nontradable good where the tradable price is normalized to 1. Since purchasing power parity is assumed to hold for the tradable sector, the real exchange rate for this small economy is the domestic consumption-based price index P^C, which is an increasing function of the nontradable price, P^N.

2.2   Government

The government's objective is to maximize the lifetime utility of the households. It provides a public good by taxing the nontradable endowment of households and borrowing in international financial markets. It is the only agent with access to borrowing and lending and it has the option of defaulting on its debt in which case the economy will be temporarily excluded from international financial markets. The government's motive for borrowing and lending is to smooth the households' consumption of the public good against the fluctuations in the tax revenue resulting from stochastic shocks to the endowments. The cost of default, therefore, is the foregone benefit of consumption smoothing for the periods of exclusion from financial markets. The default decision depends on the comparison of this cost with the one period disutility resulting from repayment of the debt.

Borrowing and lending is done using one-period bonds. Two types of bonds are available to this economy, a tradable denominated bond (T-bond) which delivers one unit of tradable good next period and a nontradable denominated bond (N-bond) which delivers an amount of tradable good equivalent to one unit of the nontradable good. When the government sells a T-bond, i.e purchases a T-bond with a negative face value, it receives q^T units of period t tradable goods and promises to pay 1 unit of period $t+1$ tradable goods next period. On the other hand if it sells an N-bond , it receives q^N units of period t tradable goods and promises to pay P^N units of period $t+1$ tradable goods next period. Since payments to foreign lenders cannot be made with nontradable goods, all transactions are settled in tradable goods, although the repayment on N-bonds is indexed to the nontradable price. In

this setting, borrowing with T-bonds is analogous to borrowing in foreign currency and N-bonds is analogous to borrowing in domestic currency. In particular, the value of repayment on T-bonds relative to N-bonds increases with a real exchange rate depreciation, i.e. with a decrease in P^N. This captures the increase in the relative burden of foreign currency to domestic currency debt with a real depreciation.

The government's budget constraint depends on the tax revenue, the beginning of the period asset position b_t, the amount of assets chosen in that period b_{t+1}, and whether it chooses to default. When the government chooses to repay its debt, the budget constraint is as follows:

$$g_t = \tau P_t^N y_t^N - q_t^T \alpha b_{t+1} - q_t^N (1 - \alpha) b_{t+1} + \alpha b_t + (1 - \alpha) P_t^N b_t \tag{3}$$

In this setup $b_{t+1} < 0$ means that the government receives $q_t^T \alpha b_{t+1} + q_t^N (1-\alpha) b_{t+1}$ units of period t tradable goods and promises to pay $\alpha b_{t+1} + (1-\alpha) P_{t+1}^N b_{t+1}$ units of period $t+1$ tradable goods next period. When $b_{t+1} > 0$, government pays $q_t^T \alpha b_{t+1} + q_t^N (1-\alpha) b_{t+1}$ units of tradable goods in period t in order to receive $\alpha b_{t+1} + (1-\alpha) P_{t+1}^N b_{t+1}$ units of period $t+1$ tradable goods next period.

When the government chooses to default, there is no further borrowing and lending and its current debt is erased. The budget constraint is then given by:

$$g_t = \tau P_t^N y_t^N \tag{4}$$

Due to the incompleteness of asset markets, the government cannot completely smooth household consumption by borrowing and lending. However, N-bonds provide better insurance than T-bonds since T-bonds pay a time-and-state invariant amount whereas repayment on N-bonds changes with the state of the economy. When the government issues N-bonds, the amount it must repay decreases in a low output state and thus provides a hedge against the output declines.

The shares of T-bonds and N-bonds are assumed to be constant in the portfolio of assets that the government holds. When it borrows or lends, the share of T-bonds is constant at α; the share of N-bonds is $(1 - \alpha)$. This formulation makes it possible to analyze the effects of debt denomination on default risk by solving the model for different α values.

Besides borrowing in international markets, government taxes the nontradable endowment of the households at a constant rate τ to finance the public good. The assumption that nontradable endowment is taxed is meant to capture the fact that because most government revenue is in domestic currency, foreign currency borrowing causes a currency mismatch in the government balance sheet. Since in this real model, the government can borrow using tradable and nontradable denominated bonds, taxation of the nontradable endowment captures this mismatch resulting from borrowing with tradable denominated bonds[5].

When the government receives its tax revenues from the households in the form of nontradable goods equal to τy^N, it exchanges this for $\tau P^N y^N$ units of tradable goods in the goods market since all final transactions of the government are settled in tradable goods. The markets for tradable and nontradable goods clears with the government's transaction.

2.2.1   Government Problem

The government's objective is to maximize the lifetime utility of households by choosing the amount of borrowing/lending and deciding whether to repay its debt given its level of outstanding assets and the endowment shocks.

The problem of the government can be formulated recursively with the state variables being b_t and s_t where b_t is the level of outstanding assets at the start of the period and s_t denotes the vector of exogenous state variables, $s_t = (y_t^T, y_t^N)$.

The value function that corresponds to the households' expected lifetime utility when

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[5]The results of the paper continue to hold if the tradable endowment is assumed to be taxed as well.

the government has access to credit markets and starts the period with assets b and shocks s is denoted by $V^o(b, s)$. Since the government decides in every period whether to default or repay, the value function satisfies:

$$V^o(b, s) = \max \left\{ V^r(b, s), V^d(s) \right\} \tag{5}$$

where $V^r(b, s)$ is the value of repaying the debt and continuing to have access to the financial markets and $V^d(s)$ is the value of defaulting.

When the government repays its debt, the value function is the following:

$$V^r(b, s) = \max_{b'} \{ U(c^T, c^N, g) + \beta E V^o(b', s') \} \tag{6}$$

subject to

$$g = \tau P^N y^N - q^T \alpha b' - q^N (1 - \alpha) b' + \alpha b + (1 - \alpha) P^N b \tag{7}$$

$$c^T = y^T - \tau P^N y^N \tag{8}$$

$$c^N = y^N \tag{9}$$

Equation (7) is the budget constraint of the government when credit markets are open and equations (8) and (9) are the domestic market clearing conditions for tradable and nontradable sectors. Note that in equations (8) and (9) the amount of tradable goods available for consumption is $y^T - \tau P^N y^N$ and the amount of nontradable goods is y^N since the government sells its nontradable tax receipts, τy^N, back to households in exchange for $\tau P^N y^N$ units of tradable goods.

The government decides on its asset holdings for the next period, b', to maximize utility subject to its budget constraint and internalizing the domestic market clearing conditions, given the level of bond holdings for the current period, b, and the shocks to the tradable and

nontradable endowments. Choosing b' will pin down the value of the public good for a given level of b since the tax rate is taken as exogenous. Given that the tax revenue fluctuates due to fluctuations in y^N and P^N, the government wants to smooth households' consumption of the public good by borrowing and lending. The value function under repayment depends on this period's utility and the maximum of next period's value functions for repayment and default, $V^o(b', s')$. The government faces the choice of defaulting or remaining in the credit relationship every period and chooses the option that gives the highest utility. Therefore, the value function for today must account for the decision of the government in the next period, which is captured by $V^o(b', s')$.

When the government defaults, the economy is excluded from credit markets temporarily and it is assumed that all of its debt is eradicated. It remains in financial autarky for a stochastic number of periods and the probability of regaining access to credit markets in any given period is θ. Furthermore, there is an additional output loss of defaulting: when the economy is in financial autarky the endowments fall by a proportion δ. This assumption follows from the empirical studies that find disruptions in trade and fall in output following defaults. Rose (2002) finds an 8% per year decline in bilateral trade flows and Puhan and Sturzenegger (2002) estimate an average fall in output of 2% per year after a default for the default episodes of 1980's. This assumption has been used in all of the recent studies on default in order to sustain reasonable levels of debt in equilibrium[6]. Therefore, the value function under default is as follows:

$$V^d(s) = U(c(c_d^T, c_d^N), g_d) + \beta E\left[\theta V^o(0, s') + (1 - \theta)V^d(s')\right] \tag{10}$$

where

$$g_d = (1 - \delta)\tau P^N y^N \tag{11}$$

$$c_d^T = (1 - \delta)(y^T - \tau P^N y^N) \tag{12}$$

[6]See Arellano (2005), Aguiar and Gopinath (2004), Yue (2005) and Sapriza and Cuadra (2005).

$$c_d^N = (1 - \delta)y^N \tag{13}$$

The government's default decision is summarized by the default function which takes the value 1 for the states in which the government finds it optimal to default. The default function is defined as

$$D(b, s) = \begin{cases} 1 & \text{if } V^d(s) \geq V^r(b, s) \\ 0 & \text{otherwise} \end{cases} \tag{14}$$

Given the government's default function, the default and repayment sets can be defined as follows: A default set, $A(b)$, is the set of exogenous shocks for which default is optimal given the level of assets b; a repayment set, $R(b)$, is the set of shocks for which repayment is optimal.

$$A(b) = \{s \, \epsilon \, Y : D(b, s) = 1\} \tag{15}$$

$$R(b) = \{s \, \epsilon \, Y : D(b, s) = 0\} \tag{16}$$

2.3 International Lenders

The international lenders are assumed to be risk neutral. They can borrow funds in the international credit markets at the risk-free interest rate r^*. It is also assumed that there is perfect competition among lenders, which drives the expected profits down to zero. Therefore, they will be willing to lend as long as they are promised the risk-free return in expected value. These conditions imply that prices of bonds are as follows:

T-Bonds:

$$q_t^T(b_{t+1}, s_t) = \frac{E_t\{(1 - D_{t+1})\}}{1 + r^*} \tag{17}$$

N-Bonds:

$$q_t^N(b_{t+1}, s_t) = \frac{E_t\{P_{t+1}^N(1 - D_{t+1})\}}{1 + r^*} \tag{18}$$

The equilibrium bond prices are consistent with the default probability of the government. For bonds that have a negative face value (government borrowing), bond prices reflect the risk-free rate and a premium for the default probability whereas bonds with positive face value (government lending) only reflect the risk-free rate. Bond prices decrease, i.e. the interest rates increase, as the default probability increases. Aside from these, the price of the N-bond also reflects the movements in the nontradable price such that a higher P^N implies a higher q^N. Since the lenders receive a higher payment next period when P^N increases, they will be willing to pay a higher price for bonds this period as well.

2.4 Equilibrium

An equilibrium for this economy can be defined as one where all agents optimize given the aggregate endowment shocks. In equilibrium households choose consumption of tradables and nontradables taking as given the nontradable price, the government's transfer of the public good and the endowment shocks. Their problem is static and their first order condition equates the marginal rate of substitution between tradable and nontradable consumption to the relative price

$$\frac{U_{c^N}(c(c^T, c^N), g)}{U_{c^T}(c(c^T, c^N), g)} = P^N \tag{19}$$

This condition shows that the nontradable price is increasing in c^T and decreasing in c^N. In the data, real exchange rate depreciations are correlated with reductions in both tradable

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and nontradable output, whereas in an endowment economy model, shocks to nontradable output generates the opposite result. In order to make the correlations generated by the model consistent with the data, the following endowment structure is assumed: endowments of tradable and nontradable output are characterized by a common stochastic trend and additionally, the tradable output has transitionary shocks around the trend, as explained in further detail in section 3. This formulation provides a simple structure for generating correlations between sectoral output and real exchange rates that are consistent with those observed in the data, using an endowment economy model[7].

The government decides on its optimal default policy given the endowment shocks and the initial level of assets, subject to the optimization of the households and the international lenders. In the case of repayment, it also chooses the new level of foreign assets. In deciding on its optimal level of asset holdings, the government knows that the prices of bonds will depend on its choice of bond holdings. Bond prices are set by the international lenders consistent with the expected default probability of the government, which depends on its choice of bond holdings. Knowing this, the government will internalize the effect of additional borrowing on the prices of bonds. When the government decides to repay, it maximizes (6) subject to (7), (8) and (9), which gives the following first order condition

$$
U_g(c,g) \left\{ \alpha q^T + (1-\alpha)q^N + b' \left(\alpha \frac{\partial q^T}{\partial b'} + (1-\alpha) \frac{\partial q^N}{\partial b'} \right) \right\}
$$

$$
= \beta E \left\{ U_g(c',g')(\alpha + (1-\alpha)P^N) \left(1 - D(b',s') \right) \right\} \tag{20}
$$

The first order condition of the government equates the marginal utility of borrowing/saving today to the expected marginal utility of the value delivered/received tomor-

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row. Today's choice of assets affects tomorrow's consumption of g only in the states where repayment is optimal. This is reflected by the fact that the marginal utility of tomorrow's consumption is multiplied by the term $(1 - D(b', s'))$. As long as P^N moves in the same direction as output, the marginal disutility of repayment decreases in a low output state and increases in a high output state for $\alpha < 1$. This effect gets stronger as α increases.

Additional borrowing affects today's utility through two channels. The first effect is an increase in utility as the government receives $\alpha q^T + (1 - \alpha) q^N$ units of tradable goods this period for each unit of bond issued. The second effect is through the change in bond prices induced by additional borrowing, which is captured by the term $b' \left(\alpha \frac{\partial q^T}{\partial b'} + (1 - \alpha) \frac{\partial q^N}{\partial b'} \right)$. As the government issues debt, bond prices decrease, since foreign lenders require a higher risk premium due to increased default risk[8]. This leads to a reduction in the marginal utility associated with additional borrowing, as the amount received by the government on additional borrowing is lower than what it would have been if the bond prices were constant. Knowing that issuing more bonds reduces the price, the government takes the change in the bond prices into account when it decides on the optimal level of bond holdings.

A recursive equilibrium for this economy can be defined as follows

Definition 1 *A recursive equilibrium is a set of functions for (i) consumption of the tradable good $c^T(b, s)$ and the nontradable good $c^N(b, s)$, and the nontradable price $P^N(b, s)$ (ii) the government's asset holdings $b'(b, s)$, public good allocation $g(b, s)$ and the default decision $D(b, s)$ and (iii) the prices for bonds $q^T(b', s)$ and $q^N(b', s)$ such that*

1. *Given the government policies, $c^T(b, s)$, $c^N(b, s)$ and $P^N(b, s)$ satisfy the household's optimization problem.*

2. *Given the bond prices $q^T(b', s)$ and $q^N(b', s)$, government's asset holdings $b'(b, s)$, public good allocation $g(b, s)$ and default decision $D(b, s)$ satisfy the government"s*

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[8]The result about default risk increasing with the level of debt has been shown by Eaton and Gersovitz (1981) and Arellano (2005).

optimization problem.

3. *Bond prices $q^T(b', s)$ and $q^N(b', s)$ satisfy the foreign creditors' expected zero profit condition and are consistent with the government's default probabilities.*

4. *The following domestic market clearing conditions hold.*

Nontradable sector market clearing condition:

$$c^N = y^N \tag{21}$$

Tradable sector market clearing condition:

$$c^T = y^T - \tau P^N y^N \tag{22}$$

3 Quantitative Analysis

The model is solved numerically using data from the Argentine economy in order to analyze the default implications of changing the share of debt denominated in tradable and nontradable goods. For the numerical solution of the model, specific functional forms are assumed for the utility function and the endowment shocks. The functional form of the utility function used in the quantitative solution is

$$U(c(c_t^T, c_t^N), g_t) = \frac{[c_t^\zeta g_t^{1-\zeta}]^{1-\sigma}}{1-\sigma}$$

where $c(c_t^T, c_t^N) = [\omega(c_t^T)^{-\eta} + (1-\omega)(c_t^N)^{-\eta}]^{-1/\eta}$ is the constant elasticity of substitution aggregator.

Aguiar and Gopinath (2003b) show that in emerging markets output fluctuations are better characterized by shocks to trend growth rather than transitory shocks around a

stable trend. Following this, in their studies of default in Argentina, both Aguiar and Gopinath (2003a) and Yue (2005) use a stochastic trend in modeling the output process since it improves the predictions of this type of models significantly. In particular, it helps generate default levels that are closer to the frequency observed in the data and improves the model's ability to match the countercyclicality of interest rates and net exports as well as the positive correlation between the interest rates and the current account. Following these studies, I model the output of tradable and nontradable sectors as a common stochastic trend. Further, I assume that the tradable endowment has transitory shocks around the trend. The endowment processes are as follows:

$$y_t^T = e^{z_t}\Gamma_t$$

$$y_t^N = \Gamma_t$$

The transitory shock follows an AR(1) process:

$$z_t = \mu_z(1 - \rho_z) + \rho_z z_{t-1} + \varepsilon_t^z$$

where $|\rho_z| < 1$.

The trend is characterized as

$$\Gamma_t = \gamma_t \Gamma_{t-1}$$

where the log growth rate follows an AR(1) process:

$$\log \gamma_t = (1 - \rho_\gamma)\log \mu_\gamma + \rho_\gamma \log \gamma_{t-1} + \varepsilon_t^\gamma$$

and $|\rho_\gamma| < 1$.

The innovations ε_t^z and ε_t^γ are jointly normally distributed with $E[\varepsilon_t^z] = E[\varepsilon_t^\gamma] = 0$, variances σ_z^2, σ_γ^2 and covariance $\sigma_{z\gamma}$.

In this formulation, transitory shocks are equivalent to shocks to the ratio of tradable to nontradable output. Since both tradable and nontradable output levels are characterized by the same trend, transitory shocks serve the dual purpose of generating the relative variation

of sectoral output levels that is observed in the data and of obtaining real exchange rate fluctuations that are consistent with the data.

Output is nonstationary with this characterization since the growth shock has a permanent effect on output. Therefore in the numerical analysis the model is detrended by Γ_{t-1}.

Table (1) presents the parameter values used in the computational analysis. These parameters are calibrated to match the empirical regularities of the Argentine economy for the period 1993 to 2004 and based on prior empirical studies of Argentina. The coefficient of relative risk aversion is set to 5, which is standard in emerging market business cycle studies. Elasticity of substitution between tradable and nontradable consumption is set to 0.5, which is close to the estimation of Gonzales and Neumeyer (2003) of 0.48. The weight on the tradable consumption in the CES aggregator, ω, is set to normalize the relative price of nontradables to be equal to one in the autarky steady state. The weight on the CES aggregator in the utility function, ζ, is set to 0.84 to match the average government expenditure to GDP ratio of 16% in Argentina. β is taken as 0.85 and the quarterly risk free interest rate is taken as 1%, which is the US Treasury Bill quarterly interest rate. The tax rate, τ, is set to 0.19 to match the average government revenue to GDP ratio of 14%.

The exogenous probability of reentering the markets is set equal to 0.1, which implies that the defaulting country will return to markets in about 10 quarters on average. This is in line with the exclusion period observed in the data by Gelos, Sahay and Sandleris (2004), who calculated the average years of exclusion to be approximately 3 years. The additional loss of output in autarky is set to 4% for debt sustained in equilibrium to approximately match the average debt to output ratio in Argentina.

To calibrate the relative sizes of the tradable and nontradable sectors in Argentina I use the classification of Arellano (2005) who assesses the degree of tradability of goods by computing the share of total trade (exports plus imports) of each sector as a percentage of total sectoral output. Based on this, the agricultural, manufacturing and energy sectors are

classified as tradable and the share of the tradable sector is 26% of total output. Therefore, the mean ratio of nontradable to tradable output is normalized to 2.78. The mean quarterly growth rate of nontradable output is calibrated to 0.2%, which implies $\mu_\gamma = 1.002$. The other parameter values for the endowment processes have been estimated by a seemingly unrelated regression method using tradable and nontradable output data.

Table 1. Parameter Values

Risk Aversion	$\sigma = 5$
Discount Factor	$\beta = 0.85$
Elasticity of Substitution	$1/(1+\eta) = 0.5$
Weight of c^T in CES	$\omega = 0.028$
Weight of c in Utility	$\zeta = 0.84$
Tax rate	$\tau = 0.19$
Output loss in default	$\delta = 0.04$
Probability of reentry	$\theta = 0.1$
Tradable Share	$y^N/y^T = 2.78$
Average Endowment Growth	$\mu_\gamma = 1.002$
AR(1) Coefficient of Growth Shock	$\rho_\gamma = 0.6043$
AR(1) Coefficient of Transitory Shock	$\rho_z = 0.6535$
Std. Dev. of Growth Shock ε^γ	$\sigma_\gamma = 0.0176$
Std. Dev. of Transitory Shock ε^z	$\sigma_z = 0.0279$
Covariance of ε^z and ε^γ	$\sigma_{z\gamma} = 0.00023$
Risk free interest rate	$r^* = 0.01$

The model is solved by a value function iteration algorithm. The AR (1) processes for income shocks are approximated with discrete Markov chains using 5 equally spaced grids for each shock using the quadrature procedure of Hussey and Tauchen (1991) and bond holdings are discretized into a grid of 400 equally spaced bond levels.

The solution algorithm is as follows

1. Assume initial bond price functions $q_0^T(b', s)$ and $q_0^N(b', s)$.

2. Using these initial prices and initial guesses for $V^r(b, s)$ and $V^d(s)$, iterate on the Bellman equations to solve for the optimal value functions and the optimal policy functions.

3. Given the optimal default decision, update the prices of bonds using equations (17) and (18). Using these prices, repeat steps 2 and 3 until the bond prices converge.

3.1   Results

The model is solved numerically for different shares of T-bonds, denoted by α. In order to analyze how default incentives change with α, I plot the price schedule of T-bonds as a function of assets for two different values of α. Plotting the price of T-bonds rather than the price of N-bonds has the advantage that the default risk can be measured directly by the price of T-bonds as it only depends on the default probability and the risk free interest rate whereas the price of N-bonds also reflects the movements in the price of nontradables.

Figure 1 plots the equilibrium price schedule of T-bonds for the highest and lowest shocks for the case where the government is trading only T-bonds, $\alpha = 1$, and only N-bonds, $\alpha = 0$. As the figure illustrates, bond prices are an increasing function of foreign assets, i.e. larger debt levels lead to higher interest rates. When the debt level is low, the government always repays its debt and the bond price is equal to the inverse of the risk free rate. As the level of debt increases, the default incentive increases and bond prices decrease, reflecting the fact that the government finds it optimal to default for some realizations of output. At even higher levels of debt, bond prices fall to zero since government defaults for all realizations of the output shocks.
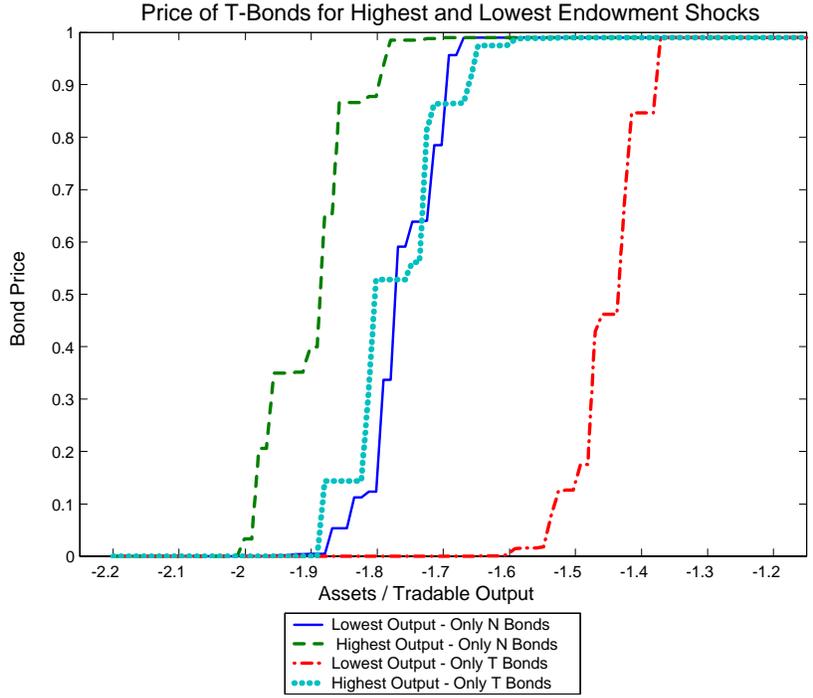
Figure 1

As the figure shows, default incentives are higher when the economy is issuing only T-bonds, $\alpha = 1$, compared with the case where it is only issuing N-bonds, $\alpha = 0$. For both the highest and the lowest shocks, the bond price faced by the economy is higher, reflecting a smaller default probability, when the government is issuing only N-bonds. Therefore, borrowing with N-bonds reduces the default risk for all levels of output and leads to lower risk premia on the interest rates.

A related result is that borrowing with N-bonds leads to a looser debt limit for the economy. With $\alpha = 1$ the government refuses to repay its debt for any realization of the output shock when debt level is equal to about -1.89 (50% of the mean aggregate output) whereas for $\alpha = 0$ this debt limit is about -2.07 (55%). Another point is that the country can borrow at the risk free rate for a higher level of debt when it only issues N-bonds. If the borrowing is done with N-bonds, the economy faces the risk free rate up to -1.65 (44%)

whereas with T-bonds this threshold is -1.38 (36.5%).

Default incentives are lower when there is more debt in N-bonds because the government's aim is to smooth the consumption of the public good and issuing N-bonds helps achieve a smoother consumption profile. The price of nontradables decreases for lower levels of output. This leads to a reduction in the tax revenue of the government, $\tau P^N y^N$, and at the same time reduces the amount to be repaid on N-bonds. Likewise both tax revenues and the value of repayment on N-bonds increase in high output states. Since the payment on T-bonds is constant, the amount of public goods provided by the government reflects the fluctuations in the tax revenue if the debt is in T-bonds. Borrowing with N-bonds decreases default risk even in the high output state in spite of the fact that repayment on N-bonds is higher than the repayment on T-bonds in this state due to P^N being greater than 1. This shows that the benefit of future consumption smoothing outweighs the cost of high repayment in this period.

Another point to note is that the model predicts that default is more likely in bad times. For a given level of assets, bond prices are lower for the low endowment state for both $\alpha = 1$ and $\alpha = 0$ cases, which means that default incentives and interest rates are higher when the output is low.

The simulation results from the benchmark calibration of the model are presented in Table (2) together with the same statistics computed for the Argentine economy. The data used to compute the statistics are quarterly real series from the first quarter of 1993 to the last quarter of 2004. The output data is obtained from the Ministry of Finance of Argentina (MECON) and the data for exchange rates, consumer price indices and current account are obtained from the IMF's International Financial Statistics (IFS) database. The interest rate data is from the dataset constructed by Neumeyer and Perri (2004) and extended by their methodology using the Emerging Market Bond Index (EMBI) of J.P. Morgan. The default rate is from Reinhart, Rogoff and Savastano (2003) and reflects the fact that Argentina defaulted on its debt five times in a 180 year time period. Real exchange rates

are constructed as the ratio of consumer price index for Argentina and US, i.e. a real exchange rate depreciation corresponds to a decrease. Output is in logs, current account is reported as a percentage of output, and all of the series are seaonally adjusted and HP filtered. The model is simulated for 10,000 periods and the statistics are the mean values over 100 simulations of 40 observations each. The simulated data are filtered the same way as the empirical data.

Table 2. Model Statistics for Argentina

	Data	Model	
		$\alpha = 1$	$\alpha = 0$
Std. Dev. of R	8.32	0.49	0.15
Std. Dev. of CA	2.53	1.51	1.24
Std. Dev. of RER	9.9	4.35	4.35
Correlation of R and Y	-0.7477	-0.0668	0.1736
Correlation of R and Y^T	-0.5666	-0.0414	0.1698
Correlation of R and Y^N	-0.7761	0.1390	0.1176
Correlation of R and RER	-0.8994	-0.2462	0.1501
Correlation of R and CA	0.9232	0.0970	-0.2625
Correlation of CA and Y	-0.8608	-0.3072	-0.2416
Correlation of RER and Y	0.6229	0.7221	0.7221
Default Rate (per 10000 quarters)	70	9.75	6
Mean Debt Output Ratio	38.5%	37.4%	44%
Increase in Welfare with $\alpha = 0$	0.52% of consumption		

As demonstrated by the data, interest rates are strongly negatively correlated with aggregate output as well as the tradable and nontradable output and positively correlated with the current account. The current account is also strongly countercyclical. The countercyclicality of the interest rates and the current account are common features of developing country business cycles that have been documented in many studies. Real exchange rates are positively correlated with the output and negatively correlated with the interest rates, which are consistent with the observation that developing countries experience real exchange rate depreciations during recessions.

The simulation results of the model yield quite different results depending on the value of α chosen for the analysis. The volatility of interest rates for the $\alpha = 0$ case is less than one third of the volatility for the $\alpha = 1$ case, and the default rate of the economy decreases by almost 40% when all of the borrowing is in N-bonds. Since N-bonds provide a better hedge against low output states, they reduce the default incentives of the economy which leads to a lower default rate and reduces the interest rate volatility as well. The reduction in the interest rate volatility is also due to the fact that the difference between the default incentives for different realizations of output is lower with N-bonds. The amount to be repaid decreases in a low output state and increases in a high output state, reducing the difference between the states in terms of default incentives. Therefore, the interest rates reflect a lower volatility.

The interest rate volatilities and default rates generated by the model are much lower than those observed in the data for both values of α. This result is consistent with the other papers that use the same type of model as my paper. In this model, the government internalizes the effect of additional borrowing on the interest rate it must pay and usually does not borrow up to the point where default is likely, which is reflected in a low default rate. Since the economy does not end up in the region that carries positive and finite risk premia very often, the interest rate volatility remains low as well. It is also worth noting that the interest rate volatility in this model is only determined by the default probability of the economy and other sources of volatility such as fluctuations in international interest rates and other external shocks or the feedback from interest rates to output are not accounted for. Despite the limitation of the model in terms of matching these statistics, a comparison for different α values is still valid since what matters most in this analysis is the difference between the two cases of α rather than matching the magnitudes observed in the data.

Another variable that changes with the value of α is the mean debt to output ratio of the economy. In the data the average ratio of debt to output for the period 1991-2001 for Argentina is about 38.5%. In the model the average amount of debt held by the economy is

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37.4% when α is 1, and 44% when α is 0. The additional debt sustained by the economy in the $\alpha = 0$ case reflects the fact that the economy faces a looser debt limit and lower interest rates when debt is indexed to the nontradables and therefore is willing to hold more debt at a lower cost.

The last row of Table (2) shows the welfare comparison for the two α values. Since borrowing with N-bonds leads to a smoother consumption profile due to the co-movement of the repayment value of debt and the level of output, welfare is higher in the case of $\alpha = 0$ compared to $\alpha = 1$. The difference in the welfare levels corresponds to a 0.52% change in permanent consumption.

The model yields quite different results for the two α values in terms of correlations as well. For the case where $\alpha = 1$, correlations are generally consistent with the data. Correlations of the interest rates with the aggregate output, tradable output and real exchange rates have the correct sign even though the magnitudes are lower. The model can also match the countercyclicality of the current account and the positive correlation of the interest rates with the current account albeit with smaller magnitudes. For the nontradable output, the model cannot match the negative correlation with the interest rates.

Modeling the output processes by a stochastic trend instead of only transitory shocks helps to generate the countercyclicality of the current account. With only transitory shocks to output, the government would typically have an incentive to save to smooth consumption when the income is temporarily high. With shocks to the trend, a positive shock increases output today but increases output even more tomorrow due to the persistence of the growth rate, and this induces the government to borrow in good times. On the other hand, the fact that the model can generate a countercyclical current account makes it difficult to generate the countercyclicality of interest rates. When borrowing increases, interest rates increase as a result of a movement along the bond price schedule. Since the economy borrows more during good times, the movement along the bond price schedule causes an increase in interest rates in the high output state. There is also a counteractive effect since the

bond price schedule shifts due to decreasing default incentives associated with high output. These two effects are in opposite directions and in the quantitative analysis the shift of the bond price schedule turns out to be bigger causing a decline in interest rates during good times and generating the countercyclicality of the interest rates. However, because of the counteractive effect, the magnitude of this decline is small. Therefore, the correlations of the interest rate with the other variables are not as strong as in the data and have the wrong sign in the case of nontradable output.

When all of the borrowing is in N-bonds ($\alpha = 0$), the correlations of the interest rates with the other variables change quite drastically. In this case, interest rates are positively correlated with aggregate and sectoral output and real exchange rates, while they are negatively correlated with current account. The reason for the model to generate procyclical interest rates in this case is that the reduction in default incentives in the high output state is less since the repayment in this state is higher due to high nontradable price. This causes the bond price schedule to shift less compared with the $\alpha = 1$ case, which is illustrated by the relatively shorter distance between the bond price schedules of the highest and lowest output shocks when α is 0 in Figure (1). Therefore, in this case the effect of the movement along the bond prices turns out to be bigger than the shift in the bond prices, which makes the interest rates procyclical. Hence, interest rates are positively correlated with aggregate and sectoral output and real exchange rates, and negatively correlated with the current account.

Figure 2 shows the last 40 observations of the average interest rates and output over 100 simulations of the model. The interest rates for $\alpha = 1$ and $\alpha = 0$ cases are computed for the same output shocks. One result that this figure illustrates is that the interest rates are lower when government issues only N-bonds. This is consistent with the higher bond prices in the $\alpha = 0$ case that were illustrated in Figure 1. Another result that this figure shows is the difference in the correlations of output and interest rates for different debt denominations. When debt is in N-bonds, the interest rates move very closely with

the output reflecting the procyclicality of interest rates that the simulation results have shown. By contrast, when debt is denominated in tradable units, interest rates move in a countercyclical way, increasing sharply when output is low.
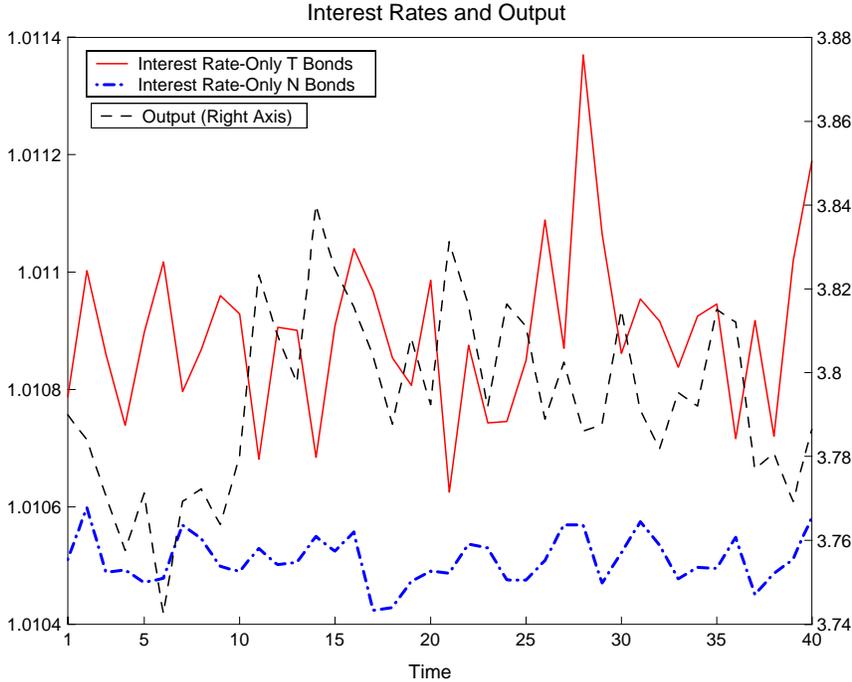

Figure 2

4   Sensitivity Analysis

This section studies the sensitivity of the results to changes in some key parameter values. The first parameter considered is the discount factor as presented in the first panel in Table 3. The most important change in the model's predictions with a change in the discount factor is that a more patient economy defaults less since the value of intertemporal consumption smoothing is higher. As a result of this, both the default rate and the interest rate volatility decrease at higher β values. The average debt holdings of the economy

increase as the discount factor decreases since a low discount factor means that the value of future consumption is discounted more heavily and the agents want to enjoy a higher consumption today by borrowing more. In comparing the model's predictions for $\alpha = 0$ and $\alpha = 1$, it is seen that the parameter changes do not affect the main conclusions. For all values of β, the default rates and interest rate volatility are lower and the economy can sustain a higher level of debt when all of the borrowing is done with N-bonds. The differences, however, are more pronounced for lower β. The cyclical behavior of interest rates are also consistent with each other for all values of the discount factor.

Table 3. Sensitivity Analysis

	Mean Debt/Output		Default Rate		Std. Dev.(R)		Corr.(R,Y)	
	$\alpha = 1$	$\alpha = 0$	$\alpha = 1$	$\alpha = 0$	$\alpha = 1$	$\alpha = 0$	$\alpha = 1$	$\alpha = 0$
Discount Factor								
$\beta = 0.9$	35%	41%	6.5	4.9	0.27	0.15	-0.2056	0.3076
$\beta = 0.85$	**37.4%**	**44%**	**9.75**	**6**	**0.49**	**0.15**	**-0.0668**	**0.1736**
$\beta = 0.8$	38.6%	46%	20.4	7	0.87	0.19	-0.1173	0.1097
Output Cost								
$\delta = 0.02$	17%	19.5%	12.2	7	0.59	0.19	0.0193	0.1009
$\delta = 0.04$	**37.4%**	**44%**	**9.75**	**6**	**0.49**	**0.15**	**-0.0668**	**0.1736**
$\delta = 0.08$	77.7%	95.7%	5.3	3.6	0.31	0.14	-0.2466	0.1789
Risk Aversion								
$\sigma = 2$	35.7%	41%	14.8	6.4	0.65	0.17	-0.0375	0.0649
$\sigma = 5$	**37.4%**	**44%**	**9.75**	**6**	**0.49**	**0.15**	**-0.0668**	**0.1736**

Another parameter that affects the results is the share of output lost with default. An increase in the output cost reduces default incentives, as a result of which default rate and interest rate volatility decrease, and the economy can sustain a higher amount of debt. The model's ability to generate a countercyclical interest rate is also affected by this parameter, where a low output cost leads to the interest rates being slightly procyclical. The relationship between the $\alpha = 0$ and $\alpha = 1$ cases, however, is not affected by this parameter.

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The last parameter that is analyzed is the risk aversion parameter. Reducing the level of risk aversion leads to higher default rates and interest rate volatility and lower debt to output ratio. Since lower risk aversion means that the value of consumption smoothing is less, the economy has a higher incentive to default and therefore can sustain lower levels of debt. Again the relationship between different α values is robust to changes in this parameter.

5 Conclusions

Foreign currency debt is regarded as a critical factor that increases sovereign default risk. This paper studies the relationship between the share of foreign currency debt and default risk in a real model with two sectors, where foreign currency debt is captured by bonds denominated in the tradable good and domestic currency debt by bonds indexed to the relative price of the nontradable good. It is a small open economy model with stochastic endowments of tradable and nontradable goods, and default risk is determined endogenously by the default probability of the government.

I compare the bond prices for different shares of tradable and nontradable denominated debt and the results show that default risk increases with an increase in the share of tradable denominated debt. Since the price of nontradables moves in the same direction as output, nontradable indexed debt acts as a hedge: in times of distress, the debt value falls, making repayment easier. On the other hand, tradable denominated debt amplifies negative shocks: during bad times, face value increases, making repayment more difficult. These findings are consistent with the correlation between real exchange rates and output that is observed in the data, and also with the debt repayment difficulties caused by foreign currency borrowing during bad times.

Aside from the fact that nontradable indexed debt leads to lower interest rates, simulation results show that both the default rate and the interest rate volatility decrease when

borrowing is done with nontradable indexed bonds. The reduction in default incentives also leads to a looser debt limit and more debt can be sustained in equilibrium. In addition, the welfare level is shown to increase as the economy borrows more with nontradable indexed bonds, since this type of borrowing enables a smoother consumption profile. Different debt denominations also affect the cyclical behavior of the interest rates where tradable denominated debt leads to countercyclical interest rates and nontradable indexed debt leads to procyclical interest rates.

The structure of this paper can be used as a basis for further research. One possible extension is to endogenize the tax rate, which was taken as fixed in this paper, in order to study the interaction between fiscal policy, default risk and debt denomination. This extension can shed light on the effects of the way emerging markets borrow on how they conduct fiscal policy. Borrowing in foreign currency increases the cost of repayment in bad times, which is exactly when these countries have limited access to foreign credit. Therefore, having to repay a high amount on foreign currency debt would force them to conduct a more contractionary fiscal policy. Given that pro-cyclical fiscal policy is a common feature of emerging markets, this extension can provide another explanation about the behavior of fiscal policy in relation to debt structure. Another possibility would be to broaden the types of indexations to include securities such as bonds indexed to GDP, inflation and terms of trade, and to compare them in terms of their effects on default incentives.

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6 Appendix

Table A1. Share of local currency debt in total international bonded debt

	1993-1998	1999-2001
Major Financial Centers	52.6%	68.3%
Euroland	23.2%	56.8%
Other Developed	17.6%	9.6%
Developing	**2.3%**	**2.7%**

Source: Eichengreen, Hausmann and Panizza (2003)
       Bank of International Settlements

Figure A2. Output and real exchange rates in developing countries

Mexico 1980-2004

Argentina 1980-2004

Turkey 1988-2004