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THE CURRENCY COMPOSITION OF SOVEREIGN DEBT

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Debauchery and Original Sin: The Currency Composition of Sovereign Debt
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ABSTRACT

This study quantitatively investigates the currency composition of sovereign debt in the presence of two types of limited enforcement frictions arising from a government's monetary and debt policy: strategic currency debasement and default on sovereign debt. Local currency debt obligations are state contingent because the real value can be changed by a government's monetary policy, and are therefore a better consumption hedge against income shocks than foreign currency debt. However, this higher degree of state contingency for local currency debt provides policymakers with more temptation to deviate from disciplined monetary policy, thus restricting borrowing in local currency more than in foreign currency. The two financial frictions combine to generate an endogenous debt frontier for local and foreign currency debts. Our model predicts that a country with less disciplined monetary policy borrows mainly in foreign currency, as the country faces a tighter borrowing limit for local currency debt than for the foreign currency debt. Our model accounts for the surge in local currency borrowings by emerging economies in the recent decade and the "Mystery of Original Sin". An important extension demonstrates that in the presence of an expectational Phillips curve, local currency debt improves the ability of monetary policymakers to commit.

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1. Introduction

“Original Sin” in the international finance literature refers to a situation in which most emerging economy central governments are not able to borrow abroad in their own currency. This concept, first introduced by Eichengreen and Hausmann (1999), is still a prevailing phenomenon for a number of emerging economies, even though the recent studies by Du and Schreger (2016 a,b), and Arslanalp and Tsuda (2014) find that the ability of emerging markets to borrow abroad in their own currency has significantly improved in the last decade.³

We study the currency composition of sovereign debt in the presence of two types of limited enforcement frictions arising from a government’s monetary and debt policy: strategic currency debasement and default on sovereign debt. We build a dynamic general equilibrium model of a small open economy to quantitatively investigate the implications of these two different enforcement frictions for a government’s debt portfolio choice. In particular, we focus on how these two frictions combine to constrain borrowing limits for local and foreign currency debt.

The temptation to debase or “debauch” the currency leads markets to restrict lending in local-currency debt for some sovereign borrowers. This temptation has been understood by economists for many years, though the literature lacks a full model of the dynamic contracting problem in a setting of debasement and default. Indeed, Keynes (1919) asserted that “Lenin is said to have declared that the best way to destroy the capitalist system is to debauch the currency.” Keynes made this point in the context of the debate over debt forgiveness after the First World War – countries could effectively renege on debt by debauching the currency.⁴

Our setting is a standard small open economy model with stochastic endowment shocks, extended to allow a benevolent sovereign government to borrow in both local and foreign currency. Strategic debasement, by reducing the real value of debt through inflation, is punished by an “Original Sin” regime in which the country is restricted to borrow only in foreign currency, and default is punished by permanent autarky. Risk neutral foreign investors in international financial markets are willing to lend to the sovereign government any amount, whether in local or foreign currency, as long as they are guaranteed an expected return of the gross risk-free rate R^* prevailing in the international financial markets. Since the real value of repayment for local currency debt can change depending on the inflation rate (currency depreciation rate),

³ For example, Du and Schreger find that the cross-country mean of the share of external government debt in local currency has increased to around 60% for a sample of 14 developing countries. The countries in the sample are Brazil, Colombia, Hungary, Indonesia, Israel, South Korea, Malaysia, Mexico, Peru, Poland, Russia, South Africa, Thailand and Turkey.

⁴ See White and Schule (2009) for a discussion of the context of Keynes’s famous statement.

the foreign investors who lend in local currency offer a contract which specifies an inflation rate at each state of the world. We consider an optimal self-enforcing contract which maximizes utility of the representative household in the small open economy and which prevents the government from breaching the contract (i.e., satisfying the enforcement constraints).

Our model predicts that the optimal contract for local currency debt allows the government to inflate away a certain fraction of local currency debt in times of bad income shocks but asks for currency appreciation in times of good shocks as a compensation for the bad times. Hence, local currency debt in our model smooths consumption of the economy better than foreign currency debt, acting like a state-contingent asset. However, due to the limited enforcement constraint arising from a government's temptation to inflate away local currency debt, the borrowing limit for local currency is endogenously constrained, thus restricting the degree of consumption smoothing function of local currency debt. On the other hand, the enforcement constraint arising from the option to fully default on its debt mainly determines the endogenous borrowing limit for foreign currency debt. With the interaction of two enforcement frictions, our model generates a debt frontier for local and foreign currency debt, inside of which the equilibrium is supported without violating the enforcement constraints.

Quantitative results show that the country with more disciplined monetary policy - represented by a country with a high cost of inflation in our model - can borrow more in both foreign and local currency, and that the country borrows mainly in local currency as it provides a better consumption hedge. The country with less disciplined monetary policy wants to borrow more in local currency, but is restricted to borrow mainly in foreign currency due to the enforcement constraints. Thus, our model can account for both "Original Sin" phenomenon for the emerging economies with less disciplined monetary policy and a recent surge in local currency borrowing by those with more disciplined monetary policy.

The term "original sin" has been applied in the literature to countries that are unable to borrow in their own currency, because empirically there seems to be very little link between the share of external debt denominated in local currency and variables such as the volatility of inflation or the size of the country's total external liabilities that perhaps should determine how much the country can borrow in local currency. We make the point that the relationship between these endogenous variables and the currency composition of debt is not straightforward. When there is lack of commitment to repay, there is a tension between the wishes of the borrowers – who may wish to have high levels of local-currency debt as a channel for smoothing consumption – and lenders who may be reluctant to lend a portfolio heavily weighted toward local-currency debt to precisely those borrowers that most desire such a portfolio. For example, borrowers with a low cost of inflation (i.e., countries with less disciplined monetary policy) prefer a portfolio more weighted toward local-currency debt, because they can use inflation more easily to make debt repayment more state-contingent. But the lender may be less likely to offer a portfolio with a large amount of local-

currency debt in such a scenario because the temptation to deviate from the terms of the debt contract may be too high for the borrowers with a low cost of inflation. The currency composition of debt and variables such as the volatility of inflation or the total debt/GDP ratio are all endogenous. They depend on parameters such as the patience and degree of risk aversion of borrowers, the cost of default and the borrower's cost of inflation. The model shows that there is no simple monotonic relationship among these variables, so it is perhaps not surprising that empirically there is no clear-cut link between the currency composition of the external portfolio and endogenous macroeconomic variables.

We also consider a version of the economy in which policymakers face an expectational Phillips curve, which allows the possibility of using monetary policy to smooth output fluctuations. However, monetary authorities are not endowed with the power to commit to a policy plan. If the economy can only borrow in foreign-currency denominated debt, or is in financial autarky, monetary policy is discretionary. But when a country is able to obtain a contract to borrow in local currency, the value of that contract acts as a commitment device that allows the policymaker to stick to a state-contingent pre-announced monetary policy.

In the remainder of section 1, we relate our approach to the literature on the currency composition of sovereign debt, and to theoretical approaches to debt contracting. In section 2, we present our formal model. Section 3 examines the model first by showing the properties of a calibrated version, including an extensive examination of the sensitivity to parameters. That section also demonstrates how the model can account for the recent increasing trend in local-currency denominated sovereign debt among emerging market economies and the “mystery of Original Sin”; offers an explanation for why we have weak empirical support for the hypothesis that monetary credibility is correlated with Original Sin; and, uses simulated method of moments to estimate parameters to match the moments of debt and other business cycle statistics for three countries. Then section 4 presents the model with the Phillips curve and demonstrates the additional gains to an economy coming from the enhanced ability to commit to a monetary policy when it can settle on a contract to borrow in local currency.

1.1 Related Literature

Our work builds on the intuition from the classical argument which attributes the predominance of foreign currency debt in international financial markets to a lack of monetary credibility. A government's strategic debasement to inflate away the real value of debt can pose a significant obstacle to issuing local currency debt (Calvo, 1978; Kydland and Prescott, 1977.)

Bohn (1990) builds a model in which governments can only commit to repayment of nominal sums, and have an incentive to inflate away debt. In Bohn's set-up, some domestic-currency debt is sustainable

because the government bears some exogenous cost to inflation. In more recent work, Ottonello and Perez (2016) study the currency composition of sovereign debt in a dynamic general equilibrium model of a small open economy with a government with limited commitment to monetary and debt policy. As in Bohn (1990), the government faces an exogenous cost of inflation. Ottonello and Perez provide a quantitative analysis of the optimal monetary policy with local-currency debt. In both models, the original-sin regime – in which governments can borrow only in foreign currency – arises only as the special case in which the cost of inflation is zero. In practice, there must be a fairly high cost of inflation internally to underpin realistic levels of domestic currency borrowing in these models. These models also do not incorporate any possibility of outright default, which plays an important role in limiting the size of sovereign debt. Phan (2017) examines an Eaton-Gersovitz style model with local and foreign currency borrowing subject to strategic default and debasement risk. That paper posits a trigger strategy for the borrower that will support borrowing in local currency, and shows that equilibrium local currency borrowing can be sustained even if the punishment for default or complete debasement of local-currency debt allows for the country to save in foreign-currency debt. It thus offers a possible resolution to the Bulow and Rogoff (1989) puzzle, but, in common with Bohn and Ottonello-Perez, it cannot account for Original Sin.

Aguilar, et al. (2013) examine a model featuring nominal debt with the possibility of self-fulfilling debt crises, as in Cole and Kehoe (2000). Since sovereign debt is nominal, the government can choose between partial default through inflation and outright default when the real burden of debt is high. The paper characterizes how inflation credibility, represented by an exogenous cost of inflation as in our model, determines the likelihood and the debt threshold of self-fulfilling debt crises, and shows that if the cost of inflation is too low, the country may be better off issuing only real (foreign-currency) debt.

Du et al (2016) also study the currency composition of sovereign debt in a two period New-Keynesian model to show how credibility of monetary policy affects the currency composition of sovereign debt. In their model, as in Bohn and Ottonello-Perez, local-currency debt is sustainable even when governments cannot commit to a monetary policy because there is an internal cost to inflation. However, in their model, the costs arise endogenously due to sticky-price distortions. In that model, the sovereign government randomly inherits or not the ability to follow through on commitments in the second period. Since ex ante there is some probability governments will keep their word, the equilibrium can maintain more domestic-currency debt.

In our model, lenders recognize that the sovereign borrower has an incentive to inflate away the debt, and that this option to inflate is more valuable to the borrower when, for example, it is suffering from low output or has high debt obligations. The lender and the sovereign sign a contract – perhaps an implicit one – that allows for more inflation in circumstances such as this. In that sense, inflation is akin to “excusable default” as in Grossman and van Huyck (1988). That paper presents a static model of debt (that is, debt is

acquired a period in advance, but can be used only as working capital. It completely depreciates after one period so it cannot be accumulated, nor can it be used to smooth consumption) in which the two parties agree to a contract that specifies debt repayment in each state of the world. If the borrowing country abrogates the contract, they fall into complete autarky. Grossman and van Huyck (1993) present a version of that model in which the debt is contracted in nominal terms, but the real repayment is determined by the inflation rate of the government. That paper is a step in the direction of our model, but differs in that the model is static and there is actually no debt. Instead, there is an agreement by the sovereign makes an agreement with risk-neutral “lenders” to receive a state-contingent payoff one period hence, which could be negative, and which has a mean of zero. The contract is written in such a way that the actual payoff is determined by the rate of inflation chosen by the sovereign, and the penalty for violating the terms of the contract is complete autarky. There is no original sin regime in which the country can borrow in foreign currency. Moreover, Grossman and van Huyck (1993) do not consider a portfolio choice problem between local and foreign currency debts as in our paper, only focusing on the implications of debasement risk on local currency debt.

Our work draws on, and is closely related to models with optimal dynamic contracts in the presence of commitment problems. Atkeson (1991), Kehoe and Levine (1993), Zhang (1997), Alvarez and Jermann (2000), and Bai and Zhang (2010) are the closest analogs. These studies show that constrained borrowing limits arising from the limited enforcement problems can cause significant distortions to allocations of an economy.

Our model differs from Atkeson (1991), Kehoe and Levine (1993), and Alvarez and Jermann (2000) in that, in our setting, there is not a full set of state-contingent claims traded internationally. Instead, our starting point resembles Eaton and Gersovitz (1981), Zhang (1997), Aguiar and Gopinath (2006), Arellano (2008), and Bai and Zhang (2010) in that we assume that only bonds that are nominally non-state-contingent can be traded. As in those papers, we do not derive this limitation endogenously, and instead appeal to the real-world observation that sovereign debt typically is not explicitly state contingent. However, our paper is unique in that it recognizes the two ways in which the debt repayments may be state contingent – because of debasement and outright default. Thus, our model shares some of the features of both strands of literature – optimal contracts but with debt that has some, but not full, state contingency. Debt denominated in home currency can be supported because of the threat of falling into the original sin regime in which all debt is denominated in foreign currency. And, foreign-currency debt can be supported in the original sin regime because of the threat of autarky.

Finally, we note that our model does share the characteristic of papers mentioned previously that governments also bear an exogenous cost to inflation. However, in contrast to the earlier work, that cost is not needed to account for why some countries can borrow in domestic-currency debt. Just the threat of

falling into the original sin regime is sufficient to allow for some domestic-currency borrowing. The exogenous cost of inflation is necessary in our model to nail down the nominal interest rate. Borrowers and lenders primarily are concerned with the real return on loans. The nominal interest rate would not matter per se, but is determined by the borrower's desire to avoid the exogenous inflation costs.

1.2 “Mystery of Original Sin” Revisited

Eichengreen, et al. (2004), and Hausmann and Panizza (2003) find weak empirical support for the idea that the level of development, institutional quality, or monetary credibility is correlated with Original Sin. These studies find that only the absolute size of the economy proxied by its GDP is robustly correlated with Original Sin. They call their finding the mystery of original sin and claim that the original sin problem of emerging market economies is exogenous to a country's economic fundamentals – it is rather related to the structure of the international financial system.

In this subsection, we replicate the findings of Eichengreen, et al. (2004) on an updated data set. They estimate a Tobit regression in which the dependent variable is $OSIN_i$, defined as $1 - \frac{\text{Securities issued by country } i \text{ in currency } i}{\text{Securities issued by country } i}$, which measures the degree of Original Sin for country i . The main explanatory variables are the GDP per capita as a proxy for the level of development of country i ; average inflation as a proxy for monetary credibility; GDP for the size of a country; and a country group dummy variable that indicates whether country i belongs to the financial center or Europe or not. Both $OSIN_i$ and x_i 's are period averages of country i . They find that after controlling for country grouping, only country size proxied by GDP is robustly correlated with a country's ability to borrow in local currency, refuting hypotheses that the emerging economies' weak financial system or lack of monetary credibility account for the Original Sin phenomenon.

We re-examine the Eichengreen, et al.'s (2004) finding with updated data from Arslanalp and Tsuda (2014), which provides a data set for externally held sovereign debt denominated in local currency for 23 emerging economies from 2004Q1 to 2015Q4.⁵ We use the share of external local currency debt in total external sovereign debt as a dependent variable (LC Share) but use the same explanatory variables (GDP per capita, average inflation, GDP, and a dummy for European countries) as in Eichengreen, et al. (2004).⁶

⁵ The countries in the sample are Argentina, Brazil, Bulgaria, Chile, China, Colombia, Egypt, Hungary, India, Indonesia, Latvia, Lithuania, Malaysia, Mexico, Peru, Philippines, Poland, Romania, Russia, South Africa, Thailand, Turkey, and Ukraine.

⁶ The data source for these explanatory variables is the World Bank.

Table 1: LC Share and GDP

	LC Share		
Log_GDP_PC	-.098 (-1.18)	-.039 (-0.45)	-.042 (-0.54)
Log_GDP			.080 (2.01)*
Europe		-.179 (-1.59)	-.119 (1.08)
Constant	1.25 (1.70)	.801 (1.07)	-1.34 (-1.06)

t-statistics in parentheses.

* Significant at 10%

Eichengreen, et al. (2004) use GDP per capita as a proxy for the level of development of a country as the quality of institutions is considered to be highly correlated with GDP per capita. They find that GDP per capita alone is highly negatively correlated with the degree of Original Sin, but after controlling for country grouping and country size, the estimated coefficient is not statistically significant even at the 5 percent level. Table 1 reports our regression on the updated data. It is a double censored (from 0 to 1) Tobit regression with explanatory variables of GDP per capita (measured in logs and denoted by Log_GDP_PC in the table), GDP, and a dummy for European countries. Consistent with Eichengreen, et al. (2004), only the size of a country proxied by GDP is statistically significant at the 10 percent level.

Table2: LC Share and Inflation

	LC Share					
Average Inflation	-.014 (-0.78)	-.008 (-0.50)				
Std Inflation			-.035(-1.64)	-.021 (-0.91)		
Max Inflation					-.009 (-1.53)	-.006 (-0.97)
Europe		-.191 (-1.85)*		-.154 (-1.37)		-.164 (-1.53)
Constant	.465 (4.07)	.509 (4.66)***	.486 (6.14)***	.505 (6.53)***	.490*** (5.77)	.517*** (6.25)

t-statistics in parentheses.

* Significant at 10%

** Significant at 5%

*** Significant at 1%

Eichengreen, et al. (2004) also investigates the cross-country correlation between Original Sin and monetary credibility by regressing $OSIN_i$ on inflation-related variables. In our regression, we use three different proxies of monetary credibility: the average of inflation, the standard deviation of inflation, and the maximum inflation rate for the sample period 2004-2015. Table 2 reports the result. Even though coefficients on all three different proxies for monetary credibility are negative, all of them are statistically insignificant, thus consistent with their findings that inflation does not explain Original Sin once the country group is controlled for. Figure 1 plots LC share and inflation variables for each country and shows that

inflation variables do not have much predictive power for which country can borrow more in local currency.⁷

Table3: LC Share and all Macro variables

	LC Share		
Log_GDP_PC	-.097 (-1.11)	-.0978 (-1.07)	-.110 (-1.21)
Log_GDP	.091 (2.31)**	.074 (1.89)*	.077 (2.00)*
Average Inflation	-.023 (-1.33)		
Std Inflation		-.030 (-1.2)	
Max Inflation			-.009 (-1.43)
Europe	-.055 (-0.49)	-.026 (-0.2)	-.026 (-0.22)
Constant	-1.041 (-0.84)	-.633 (-0.47)	-.591 (-0.45)

t-statistics in parentheses.

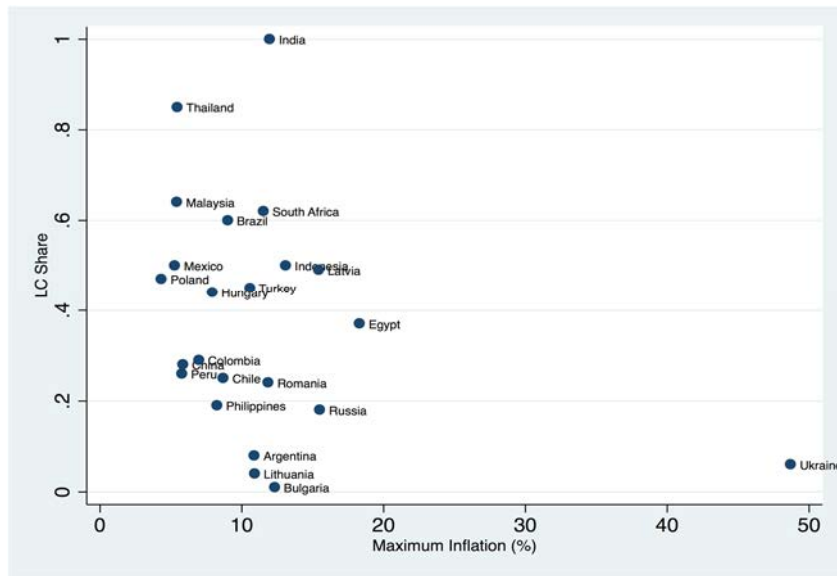
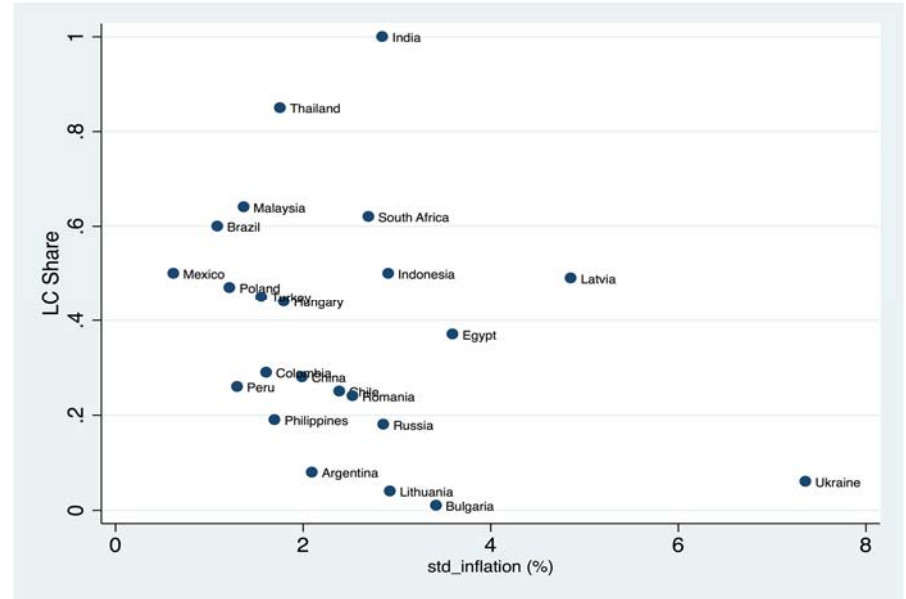
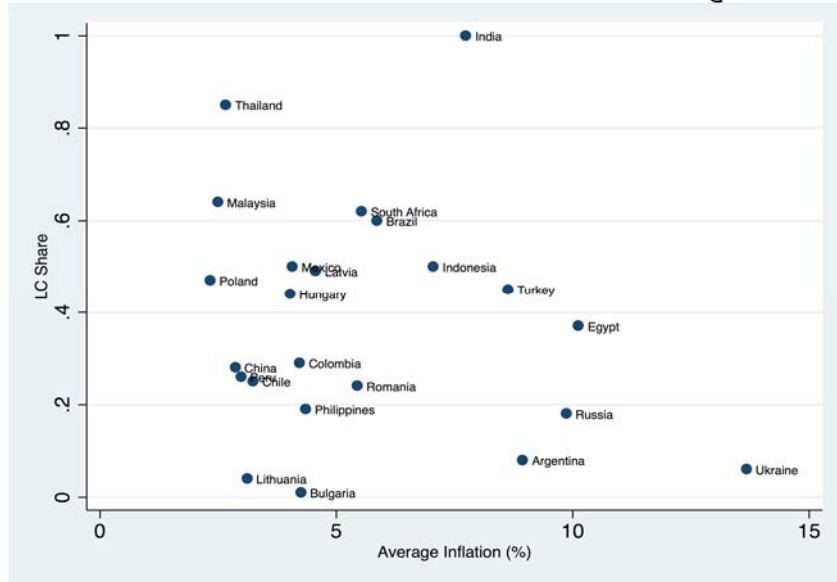
* Significant at 10%

** Significant at 5%

Table 3 shows the results of multivariate regression with all the main explanatory variables included as in Eichengreen, et al. (2004). Consistent with their finding, country size is the only explanatory variable which is statistically significant. Even though emerging economies' ability to borrow in local currency has improved greatly in recent decades, our finding suggests that "the mystery of Original Sin" seems to still exist today. In the next section, however, we will provide a structural model to explain the recent surge in local currency borrowings by emerging economies and why we observe the mystery of Original Sin.

⁷ India's LC share has been around 99% over the entire sample period, so that it can be considered as an outlier for our sample. Without India's data, however, the main regression results are robust.

Figure 1: LC Share and Inflation



Note: the LC share and the inflation related variables for country i are period averages of country i from 2004-2015.

2. The Model Economy

We consider a standard small open economy model, extended to allow a government to borrow in both local and foreign currency from foreign lenders in international financial markets. The representative household receives stochastic endowment shocks every period and has preferences given by

$$E_0 \sum_{t=0}^{\infty} \beta^t [u(c_t) - C(\pi_t - \bar{\pi})] \quad (1)$$

where β denotes the time discount factor, c_t consumption, π_t gross inflation rate at period t (i.e., $\frac{P_t}{P_{t-1}}$),

and $\bar{\pi}$ the target inflation rate of the country. The period utility function $u(\cdot)$ is strictly increasing and strictly concave, and satisfies the standard Inada conditions. Following Barro and Gordon (1983), we introduce the cost of inflation in the form of utility loss $C(\pi_t - \bar{\pi})$, which is assumed to be symmetric around the target inflation rate $\bar{\pi}$; any deviation in inflation rates from the target inflation rate incurs utility loss. The sovereign government is benevolent and makes borrowing, default, and debasement decisions so as to maximize social welfare of this economy.

There is one tradable consumption good in this economy. The random income shock y_t has a finite support $Y = \{y^1, y^2, \dots, y^N\}$ and follows a Markov process with a transition function $\Pr(y_{t+1} | y_t)$. The history of the income shock is denoted by s^t . Let P_t and P_t^* respectively be the price of the consumption good in Home (i.e., the small open economy) and Foreign country. The budget constraint in nominal terms is given by

$$P_t c_t + S_t P_t^* b_{t+1}^{for} + P_t b_{t+1}^{loc} = P_t y_t + R^* S_{t-1} P_{t-1}^* b_t^{for} + i_t P_{t-1} b_t^{loc},$$

where S_t is the exchange rate, $b_t^{for} \leq 0$ foreign currency debt, $b_t^{loc} \leq 0$ local currency debt, i_t the gross interest rate on local currency debt, R^* a constant gross risk-free rate prevailing in the international financial market.⁸ We assume that the law of one price holds and the foreign price P_t^* is normalized to be

⁸ Since we investigate the currency composition of two types of sovereign debts, we don't allow the government to accumulate assets. However, it would not be plausible to assume that the foreign lenders issue debt in the currency of the small home country. The small open economy could not punish a large lender such as the U.S. either for default or debasement. In any case, the no accumulation constraint is not binding in the simulations for the foreign currency asset.

one, so that $P_t = P_t^* S_t = S_t$. Then the budget constraint for the economy, conditional on the sovereign government rolling over its debt by following the terms of contract, is given in real terms by

$$c_t + b_{t+1}^{for} + b_{t+1}^{loc} = y_t + R^* b_t^{for} + \frac{i_t b_t^{loc}}{\pi_t}. \quad (2)$$

When the government does not breach the contract, it solves a portfolio problem between local and foreign currency debt to maximize social welfare of the economy. b_t^{for} and b_t^{loc} are non-contingent bonds in nominal terms, but depending on the inflation rate π_t , the real rate of interest on local currency debt is $\frac{i_t}{\pi_t}$, which is state-contingent. Finally, we impose the natural debt limit following Aiyagari (1994) given by

$$(b_{t+1}^{for} + b_{t+1}^{loc}) \geq -D, \quad (3)$$

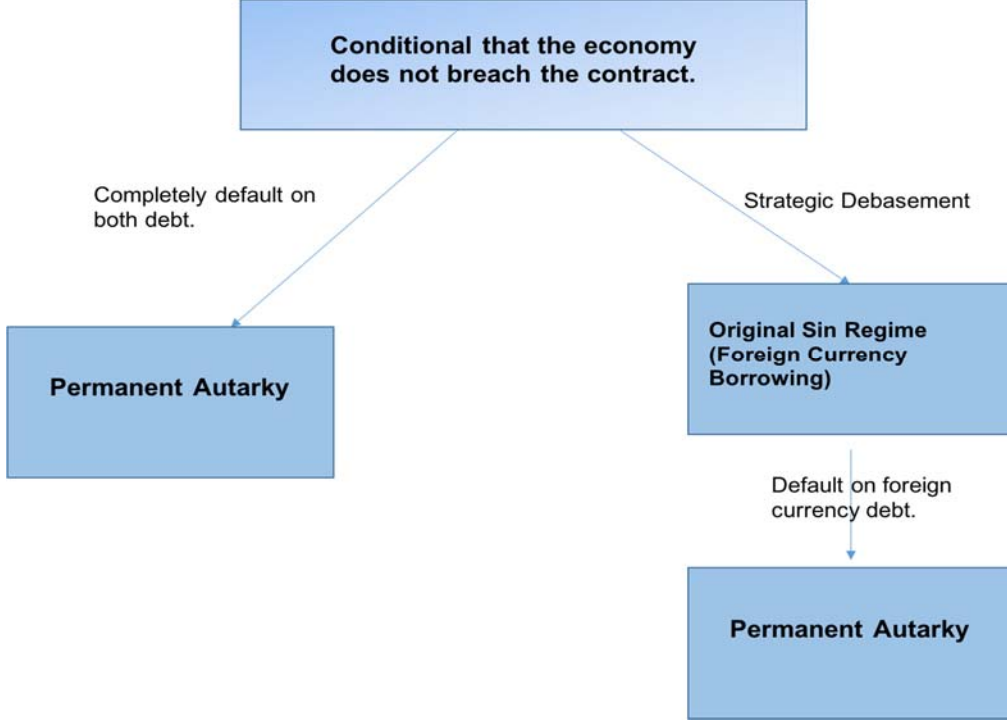
where $D = \underline{y} / (R^* - 1)$ and \underline{y} is the lowest income shock.

The government can breach the debt contract in the following two ways: First, the government can fully default on its debt denominated in both local and foreign currency simultaneously⁹. Second, the government can debase its currency more than required in the contract for local currency debt, the terms of which will be specified in detail later. Thus our model features two types of enforcement (commitment) frictions arising from a government's monetary and debt policy: strategic default and debasement. This is a novel feature of our model and we quantitatively study how these two frictions affect the currency composition of sovereign debt.

When the government fully defaults on its debts, the economy enters permanent autarky, during which it loses access to international financial markets and suffers from a drop in income. When the government breaches the contract by debasing its currency, the country is restricted to borrow only in foreign currency, thus entering the "Original Sin" regime. When the government in this regime defaults on its foreign currency debt, the economy also enters permanent autarky. Figure 2 summarizes the two different types of breaches of the debt contract and their consequences.

⁹ Selective default on a certain type of debt is not allowed in our model, consistent with practices in sovereign debt markets. See Broner et. al. (2010) for a theoretical study on this problem.

Figure 2: Two Types of Breaches of Contract



Local Currency Debt Contract

Foreign lenders in competitive international financial markets are risk-neutral and have deep pockets. There are two types of lenders: lenders who lend in local currency and those who lend in foreign currency. Both are willing to lend to the sovereign government any amount, whether in local or foreign currency, as long as they are guaranteed an expected return of the gross risk-free rate R^* prevailing in the international financial markets. Even if the local currency debt is non-contingent in nominal terms with a gross interest rate i_{t+1} , depending on the government's choice on the inflation rate π_{t+1} (or equivalently currency depreciation rate), the real rate of interest on local currency debt $\frac{i_{t+1}}{\pi_{t+1}}$ can differ. We consider the following recursive contract for the *local* currency debt, which consists of two components: a nominal gross interest rate i_{t+1} and state contingent inflation rates in the next period π_{t+1} .

$$i_{t+1} = \Pi(b_{t+1}^{for}, b_{t+1}^{loc}, y_t) \quad (4)$$

$$\pi_{t+1} = \Pi(b_{t+1}^{for}, b_{t+1}^{loc}, y_t, y_{t+1}) \quad (5)$$

When the sovereign government borrows b_{t+1}^{for} and b_{t+1}^{loc} in foreign and local currency in period t , the contract charges a nominal gross interest rate i_{t+1} on the local currency debt b_{t+1}^{loc} . Moreover, the contract asks for a certain inflation (currency depreciation) rate depending on the realization of y_{t+1} in period $t+1$.

Since the foreign investors who lend in local currency must be guaranteed an expected return of a gross risk-free rate R^* for the local currency debt, we have the following zero-profit condition on the contract:

$$R^* = \sum_{y_{t+1}} Pr(y_{t+1} | y_t) \frac{i_{t+1}(b_{t+1}^{for}, b_{t+1}^{loc}, y_t)}{\pi_{t+1}(b_{t+1}^{for}, b_{t+1}^{loc}, y_t, y_{t+1})} \quad (6)$$

Note that there is y_t as well as y_{t+1} in $\Pi(\cdot)$ because of the persistent income shock process $Pr(y_{t+1} | y_t)$ in equation (6).

On the other hand, the foreign lenders charge the gross risk-free rate R^* on the foreign currency debt as typical of a standard small open economy model featuring a non-contingent debt. From now on, x_t denotes the vector of state variables at period t , which consists of $(b_t^{for}, b_t^{loc}, y_{t-1}, y_t)$.

Value of Debasement

Due to the limited commitment (enforcement) of monetary policy, the sovereign government can debase its currency at any time by choosing a higher inflation rate than $\pi_t(x_t)$ in the contract to inflate away a certain fraction of local currency debt. When the government breaches the contract by debasing its currency, the country is restricted to borrowing *only* in foreign currency thereafter as a punishment. That is, the country enters the regime of “Original Sin” or foreign currency borrowing. Note that the foreign investors who lend in foreign currency do not incur any losses even when the government breaches the local currency contract by inflating away the local currency debt; they are willing to lend to the government in foreign currency after the debasement. The foreign investors who lend in local currency thus cannot impose financial autarky on the government for breaching the contract by debasing its currency as in the case of default, because the foreign currency lenders will not co-operate with them in the punishment of financial autarky.

The value of debasement is given by

$$V^{debase}(b_t^{for}, b_t^{loc}, y_{t-1}, y_t) = \max_{\pi_t \neq \pi_t(x_t), b_{t+1}^{for}} [u(c_t) - C(\pi_t - \bar{\pi})] + \beta E_t V^{for}(b_{t+1}^{for}, y_{t+1}) \quad (7)$$

subject to the budget constraint:

$$c_t + b_{t+1}^{for} = y_t + R^* b_t^{for} + \frac{i_t b_t^{loc}}{\pi_t}$$

$$b_{t+1}^{for} \geq -D.$$

$V^{for}(\cdot)$ denotes the value of borrowing in foreign currency after the debasement.

Value of Foreign Currency Borrowing (Original Sin Regime)

The value of foreign currency borrowing is given by

$$V^{for}(b_t^{for}, y_t) = \max_{b_{t+1}^{for}} u(c_t) + \beta E_t V^{for}(b_{t+1}^{for}, y_{t+1}) \quad (8)$$

subject to the following constraints:

$$c_t + b_{t+1}^{for} = y_t + R^* b_t^{for}$$

$$V^{for}(b_{t+1}^{for}, y_{t+1}) \geq V^{def}(y_{t+1}) \text{ for all } y_{t+1} \quad (9)$$

$$b_{t+1}^{for} \geq -D. \quad (10)$$

Equation (9) is the enforcement constraint related to the government's default decision and requires that the continuation value of foreign currency borrowing be equal to or higher than the value of default in any possible future contingencies. Note that this enforcement constraint determines an endogenous debt limit for foreign currency borrowing that can be supported in equilibrium for the Original Sin regime. $V^{def}(y_{t+1})$ denotes the value of default when the government chooses to default on its debt, whether in local or (and) foreign currency.

Value of Default

Upon default, the economy enters permanent financial autarky during which the economy loses access to the international financial market, and the economy suffers a drop in income. The value of default is given by

$$V^{def}(y_t) = u(c_t) + \beta E_t V^{def}(y_{t+1}) \quad (11)$$

$$c_t = h(y_t), \quad (12)$$

where $h(y_t) < y_t$. $h(y_t)$ represents a decrease in income associated with default, which is consistent with empirical findings in the sovereign debt literature.

Original Problem under the Optimal Contract

The contract is optimal in the sense that it maximizes utility of the representative household in the small open economy. Moreover, the contract is self-enforcing in the sense that the government under this contract does not have any incentive to breach the contract. The original problem under the optimal self-enforcing contract is given by:

$$\max_{\{c_t, b_{t+1}^{for}, b_{t+1}^{loc}, \pi_{t+1}, i_t\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t \left[u(c_t(s^t)) - C(\pi_t(s^t) - \bar{\pi}) \right] \quad (13)$$

subject to (1) the budget constraint, (2) the enforcement constraint, (3) the expected zero profit condition for the lenders.

$$c_t(s^t) + b_{t+1}^{for}(s^t) + b_{t+1}^{loc}(s^t) = y_t(s^t) + R^* b_t^{for}(s^{t-1}) + b_t^{loc}(s^{t-1}) \frac{i_t(s^{t-1})}{\pi_t(s^t)} \quad (14)$$

$$E_t \sum_{s=t}^{\infty} \beta^{s-t} \left[u(c_s) - C(\pi_s - \bar{\pi}) \right] \geq \max \left\{ V_{def}(y_t), V_{debase}(b_t^{for}, b_t^{loc}, y_{t-1}, y_t) \right\} \quad (15)$$

$$R^* = \sum_{y_t} Pr(y_t | s^{t-1}) \frac{i_t(s^{t-1})}{\pi_t(s^t)} \quad (16)$$

Then, an equilibrium in this model is a sequence of inflation rates and interest rates on local currency debt $\pi(s^t)$ and $i_t(s^{t-1})$ in the contract, and allocations $\{c(s^t), b_{t+1}^{for}(s^t), b_{t+1}^{loc}(s^t)\}$ such that the contract and the allocations solve the maximization problem subject to the budget constraint (equation (14)), the enforcement constraint (equation (15)), and the lender's expected return condition (equation (16)).

Note that the enforcement constraint equation (15) has two value functions on the right hand side: the values of debasement and default. These enforcement constraints come from two different types of limited

commitment problems regarding the government's monetary and debt policy. These two enforcement constraints combine to generate an endogenous debt frontier for local and foreign currency debt, thus determining the currency composition of sovereign debt.

Recursive Formulation of the Original Problem

Since the enforcement constraint equation (15) has expected values of future variables, we cannot use the standard recursive Bellman equation, as pointed out first by the classical paper by Kydland and Prescott (1977). This is a common problem shared with many economic models dealing with time-inconsistent government policy. However, our original problem is recast recursively following Atkeson (1991), which uses the solution techniques of Abreu et al (1990) and is extended by Bai and Zhang (2010) for incomplete asset markets models.

Before the income shock is realized at period t , the optimal contract chooses a nominal interest rate i_t and an inflation rate π_t (i.e., currency depreciation rate) for each state for the period t that maximizes the expected sum of value functions V^c 's.

$$W(b_t^{for}, b_t^{loc}, y_{t-1}) = \max_{i_t, \pi(x_t)} \sum_{y_t} Pr(y_t | y_{t-1}) V^c(b_t^{for}, b_t^{loc}, y_{t-1}, y_t; \pi(x_t)) \quad (17)$$

subject to the lender's expected zero profit condition:

$$R^* = \sum_{y_t} Pr(y_t | y_{t-1}) \frac{i_t(b_t^{for}, b_t^{loc}, y_{t-1})}{\pi_t(b_t^{for}, b_t^{loc}, y_{t-1}, y_t)} \quad (18)$$

After the income shock is realized at period t , taking $\pi(x_t)$ as given, the government solves the following value function:

$$V^C(b_t^{for}, b_t^{loc}, y_{t-1}, y_t; \pi(x_t)) = \max_{b_{t+1}^{for}, b_{t+1}^{loc}} [u(c_t) - C(\pi_t - \bar{\pi})] + \beta W(b_{t+1}^{for}, b_{t+1}^{loc}, y_t) \quad (19)$$

$$c_t + b_{t+1}^{for} + b_{t+1}^{loc} = y_t + R^* b_t^{for} + \frac{i_t b_t^{loc}}{\pi(x_t)} \quad (20)$$

$$V^C(b_{t+1}^{for}, b_{t+1}^{loc}, y_t, y_{t+1}; \pi(x_{t+1})) \geq \max \{V^{debase}(b_{t+1}^{for}, b_{t+1}^{loc}, y_t, y_{t+1}), V^{def}(y_{t+1})\} \text{ for all } y_{t+1} \quad (21)$$

Following Atkeson (1991), and Bai and Zhang (2010), we solve the above problem iteratively starting with sufficiently high initial values W_0 and V_0 , where the subscript denotes the number of iterations. At each iteration, the domain D_0 of W_0 and V_0 is updated such that it solves the maximization problems of equations (17), (19) subject to the budget and the enforcement constraints equations (20), (21). The sequences of $\{W_n\}$, $\{V_n\}$, and $\{D_n\}$ are decreasing, finally converging to W , V , and D , respectively. Then, we obtain combinations of (b^{loc}, b^{for}) in D that satisfy the budget and the enforcement constraints.

For π_t and i_t , we have the following first order conditions.

$$[\pi(x_t^i)]: u'(c(x_t^i))i_t b_t^{loc} + C'(\pi(x_t^i))\pi(x_t^i)^2 = u'(c(x_t^j))i_t b_t^{loc} + C'(\pi(x_t^j))\pi(x_t^j)^2 \text{ for } i \neq j \quad (22)$$

$$[i_t]: \sum_{y_t^j \in Y} \Pr(y_t^j | y_{t-1}) C'(\pi(x_t^j)) \pi(x_t^j) = 0, \quad (23)$$

where $x_t^i \equiv (b_t^{for}, b_t^{loc}, y_{t-1}, y_t^i)$, and $y^i < y^j$ for $i < j$.

The first order condition with respect to π_t shows that the first term on the left hand side in equation (22) is the marginal benefit of an increase in an inflation rate: an increase in inflation rates leads to a decrease in the real value of local currency debt, thus increasing consumption at the state of (x_t^i) . Note that the first term on the left hand side in equation (22) has b_t^{loc} : the more local currency debt the economy holds at period t , the higher the marginal benefit of an increase in inflation rates is. The second term on the left hand side is the marginal cost of the increase in the inflation rate at the state of (x_t^i) . If there is an increase in the inflation rate (i.e., depreciation) at the state (x_t^i) , the zero profit condition for the foreign lenders (equation (18)) requires a decrease in inflation rates (i.e., appreciation) at other high income states (x_t^j) to compensate for the loss incurred to the lenders at state (x_t^i) . The right hand side in equation (22) is the marginal cost associated with the appreciation of the currency at the state (x_t^j) . That is, the optimal contract equates the marginal benefit and cost across states at an optimum.

The first order condition with respect to i_t shows that at an optimum, the nominal interest rate i_t on local currency debt is chosen to minimize the expected sum of costs of inflation across states. Note that

with a symmetric cost of inflation around the target inflation rate $\bar{\pi}$, the marginal cost at $\pi_t < \bar{\pi}$ is negative.

The following proposition and corollary characterize the state-contingent nature of local currency debt in our model.

Proposition 1: *Suppose that there is no enforcement constraint (equation (21)) and that there is no cost of inflation (i.e., $C(\pi_t - \bar{\pi}) = 0$ for all π_t). Then the optimal contract for interior solutions is such that*

$$c(x_t^i) = c(x_t^j) \text{ for any } i \neq j. \quad (24)$$

Proof: See the Appendix.

This proposition shows that local currency debt has characteristics similar to Arrow-Debreu securities in the complete markets model. Without any financial frictions and cost of inflation, local currency debt completely smooths consumption of the representative household across states.

Corollary 1: *Suppose that $y_t^i \leq y_t^j$. Then, under the same conditions as the proposition 1, π_t in the optimal contract is such that*

$$\pi(x_t^i) \geq \pi(x_t^j) \quad (25)$$

The corollary shows that without any frictions, the optimal contract for local currency debt allows the government to depreciate its currency in times of bad income shocks but asks for currency appreciation in times of good income shocks as a compensation to the investors for bad times. Thus, compared to foreign currency debt, local currency debt under the optimal contract is a better instrument for consumption hedging against income shocks, especially when there is no cost of inflation.

Debt Frontier

\underline{B}^{loc} is defined as follows:

$$\underline{B}^{loc} \equiv \max_{y_t \in Y} \{ \underline{b}^{loc}(y_t) \},$$

where $\underline{b}^{loc}(y_t)$ is the borrowing limit for local currency for y_t and is defined in the following:

$$\underline{b}^{loc}(y_t) \equiv \max_{y_{t+1} | \Pr(y_{t+1} | y_t) > 0} \left\{ b_{t+1}^{loc}(y_{t+1}) : V^c(0, b_{t+1}^{loc}(y_{t+1}), y_t, y_{t+1}) = \max \left[V^{debase}(0, b_{t+1}^{loc}(y_{t+1}), y_t, y_{t+1}), V^{def}(y_{t+1}) \right] \right\} \quad (26)$$

That is, $\underline{b}^{loc}(y_t)$ is the maximum amount of the local currency borrowing for y_t without any foreign currency borrowing (i.e., $b^{for} = 0$) that does not violate the enforcement constraints under all future contingencies. Note that b denotes bond holdings, not debt, so that for any amount of debt greater than $\underline{b}^{loc}(y_t)$ (i.e., any $b < \underline{b}^{loc}(y_t)$), the country would be tempted to default or debase for certain y_{t+1} , so that it would not be sustainable and not allowed in the contract. Then \underline{B}^{loc} can be interpreted as the maximum amount of the local currency borrowing with $b^{for} = 0$ without violating the enforcement constraints at any date and any state.

Debt frontier $\underline{B}^{for}(b^{loc})$ is defined in the following:

$$\underline{B}^{for}(b^{loc}) \equiv \max_{y_t \in Y} \left\{ \underline{b}^{for}(b^{loc}, y_t) \right\}, \text{ for } \underline{B}^{loc} \leq b^{loc} \leq 0,$$

where $\underline{b}^{for}(b_{t+1}^{loc}, y_t)$ is defined in the following:

$$\underline{b}^{for}(b_{t+1}^{loc}, y_t) \equiv \max_{y_{t+1} | \Pr(y_{t+1} | y_t) > 0} \left\{ b_{t+1}^{for}(y_{t+1}) : V^c(b_{t+1}^{for}(y_{t+1}), b_{t+1}^{loc}, y_t, y_{t+1}) = \max \left\{ V^{debase}(b_{t+1}^{for}(y_{t+1}), b_{t+1}^{loc}, y_t, y_{t+1}), V^{def}(y_{t+1}) \right\} \right\},$$

$$\text{for } \underline{b}^{loc}(y_t) \leq b_{t+1}^{loc} \leq 0. \quad (27)$$

That is, $\underline{b}^{for}(b_{t+1}^{loc}, y_t)$ is the maximum amount of foreign currency borrowing which satisfies the enforcement constraints under all future contingencies, given that the economy chooses to borrow b_{t+1}^{loc} in local currency for y_t . Any more borrowing than $\underline{b}^{for}(b_{t+1}^{loc}, y_t)$ (i.e., $b^{for} < \underline{b}^{for}(b_{t+1}^{loc}, y_t)$) in foreign currency violates the enforcement constraints for certain y_{t+1} , thus not supported in equilibrium.

For any combinations of (b^{loc}, b^{for}) inside the debt frontier $\underline{B}^{for}(b^{loc})$, a sovereign government honors its debt contract with the foreign investors at any date and any state. The debt frontier is in the same spirit as no default borrowing constraint in Zhang (1997) and solvency constraints in Alvarez and Jermann (2000).

Definition 1: If $\underline{b}^{loc}(y) = 0$ and $\underline{b}^{for}(0, y) < 0$ for all $y \in Y$ in equilibrium, the model economy is in the “Original Sin” Regime.

When the economy is not able to borrow any amount in local currency for any date and any state, we have that $\underline{b}^{loc}(y) = 0$ for all $y \in Y$. In this case, the value of the contract reduces to the value of foreign currency borrowing (that is, the “Original Sin” Regime).

Proposition 2: For sufficiently low values of β for which the value of foreign currency borrowing exists, the economy is in the “Original Sin” Regime.

Proof: See the Appendix.

If the discount factor β is sufficiently small, the value of debasement is high relative to the value of the contract for certain states of the world. Then, the local currency contract cannot be constructed, as the enforcement constraints are not satisfied for all future contingencies. In this case the economy must stay in the “Original Sin” regime.

Proposition 3: Suppose that the cost of the inflation function $C(\pi_t - \bar{\pi}; \xi)$ is differentiable with respect to ξ , and that $C(\pi_t - \bar{\pi}; \xi)$ is strictly increasing and convex in ξ for any given π_t . Moreover, suppose that for any given y_t and y_{t+1} , $V^{debase}(0, \underline{B}^{loc,L}, y_t, y_{t+1}; \xi^L)$ is sufficiently larger than $V^{def}(y_{t+1})$ (i.e., the equality in equation (26) holds with the value of debasement.) Then $\underline{B}^{loc,H} \leq \underline{B}^{loc,L}$ for $\xi^H > \xi^L$.

That is, when the temptation to debase is sufficiently high, a country with a higher cost of inflation has a more relaxed borrowing limit for local currency debt.

Proof: See the Appendix.

Proposition 3 shows that the degree of monetary credibility represented by the cost of inflation parameter ξ determines the borrowing limit for local currency debt. This is consistent with the recent empirical findings by Du et al (2016), which shows that in the recent decades even developing countries with more disciplined monetary policy have managed to borrow more in local currency, which departs from the trend of “Original Sin” in the 70’s and 80’s.

Proposition 4: Suppose that the cost of inflation is zero for all π_t . Then the equilibrium interest rate on local currency debt i_{t+1} is indeterminate.

The proof is straightforward and is from the lender's expected zero profit condition equation (18). With no cost of inflation, the real interest rate on local currency debt $\frac{i_{t+1}}{\pi_{t+1}}$ only matters for the equilibrium allocations.

Proposition 5: *If $C(\pi_t - \bar{\pi}) = \infty$ for any $\pi_t \neq \bar{\pi}$, then $\pi_t(s^t) = \bar{\pi}$ for all t . Moreover, the currency composition between foreign and local currency debts is indeterminate.*

Proof: See the Appendix.

When the cost of inflation is infinite, foreign currency debt becomes the same as local currency debt, so the currency composition between the two types of debts is indeterminate.

3. Quantitative Results

Table 4: Parameters

Parameter			
γ	2	Risk aversion	Literature
β	0.96	Time Discount Factor	Time Period is a year
r_f	4%	Risk Free Rate	Literature
ϵ	0.04	Std of Income	Volatility of income
ξ	different values	Cost of Inflation	Volatility of inflation
μ	1	Mean Income	-
λ	3%	Default Cost	Benjamin and Wright (2009)
ρ	0.7	Persistence of Income Shock	-

3.1 Parameters and Functional Forms

In this section, we solve the model numerically and simulate it to investigate quantitative implications of the two limited commitment frictions for the currency composition of sovereign debt.

Table 4 reports the parameters used for the benchmark calibration. A period is a year. We use the standard CRRA utility function $\frac{c^{1-\gamma} - 1}{1-\gamma}$ and set γ to be 2, which is also standard in the literature. The time discount factor β is set to be 0.96.

- The income shock takes on two values, y_H and y_L , where $y_H = \mu + \varepsilon$ and $y_L = \mu - \varepsilon$. μ is the mean income and ε the standard deviation of the income shock. The mean income μ is normalized to be one, and ε is set to be 4%. As a benchmark case, the persistence of the income shock ρ (i.e., $\Pr(y_H | y_H) = \Pr(y_L | y_L)$) in the two state Markov Chain is set to be 0.7.
- We use the quadratic cost of inflation given by

$$C(\pi) = \xi(\pi - 1)^2, \quad (28)$$

which implies that the target inflation rate $\bar{\pi}$ is normalized to be one.

- The cost of default during autarky is in the form of a drop in income:

$$h(y_t) = (1 - \lambda)y_t \quad (29)$$

As with other studies in the sovereign debt literature, we assume that the economy suffers from a drop in income during autarky. As a benchmark value, we set λ to be 0.03 from Benjamin and Wright (2009).

3.2 Model Moments

Table 5: Model Moments

	$\xi = 0.005$	$\xi = 0.105$
\underline{B}^{loc} (% of GDP)	31.2%	50.1%
Average Total Debt (% of GDP)	63.65%	62.70%
Average LC Debt (% of GDP)	13.77%	34.47%
Average LC Share (%)	22.92%	58.45%
Corr (GDP, Total Debt)	-0.41	-0.43
Corr (GDP, LC Share)	0.22	0.40
Corr (GDP, inflation rate)	-0.85	-0.84
Std (inflation rate)	13.57%	2.29%

Table 5 compares the model moments of debt and inflation for the cases of low ($\xi = 0.05$) and high ($\xi = 0.105$) cost of inflation. To get the statistics in Table 5, we simulate the model 5000 times and the first 1000 simulated data points are removed to rule out any effects of initial conditions.

For the high cost of inflation, the local currency debt limit \underline{B}^{loc} is 0.501, whereas for the low cost of inflation, \underline{B}^{loc} is 0.312. That is, a high cost of inflation is associated with a more relaxed borrowing limit for the local currency debt. The total debt – the sum of local and foreign currency debts in real terms – is on average not much different between the two cases. However, the average local currency debt and local currency share in total debt shows a significant difference: the economy with a high cost of inflation borrows on average more (34.47% of its GDP) than that with a low cost of inflation (13.77% of its GDP). Moreover, the local currency debt shares for the high and low cost inflation cases are 58.45% and 22.92%, respectively. As the local currency debt limit with a high cost of inflation is more relaxed than that with a low cost of inflation, the economy with a high cost of inflation tends to borrow more in local currency. For both cases, the correlation between GDP and inflation is negative at around -0.85, consistent with Corollary 1: the optimal contract asks for currency depreciation in bad income times but asks for appreciation in good income times. However, the economy with a low cost of inflation uses monetary policy more actively to use local currency debt as a consumption-hedging device. The last row of the table reports volatilities of inflation for the two cases.

3.3 Debt Frontiers for Different Costs of Inflation

Figure 3: Debt Frontiers with Different Costs of Inflation ($\xi = 0.005$ and $\xi = 0.0105$)

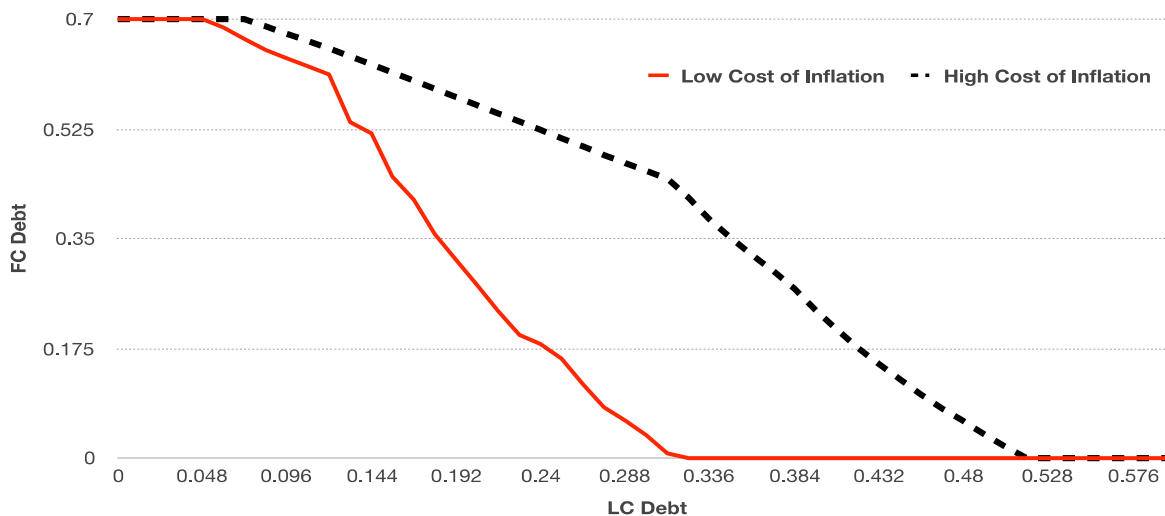


Figure 3 plots debt frontiers for two different values of the cost of inflation ($\xi = 0.005$ and $\xi = 0.105$).

The debt frontier shows the maximum debt limits for both types of debts supported in equilibrium without violating the enforcement constraints. For the case of the high cost of inflation, the debt frontier is a dashed black line, and for the case of the low cost of inflation, the debt frontier is a red solid line. The region under the frontier is the feasible combinations of local and foreign currency debts that the government can choose without violating the enforcement constraints at any time and any state. Note that the region for the high cost of inflation is strictly larger and covers that for the low cost of inflation. That is, the country with more disciplined monetary policy is able to borrow more in both local and foreign currency debts. However, the debt frontier for the low cost of inflation is more restricted along the dimension of local currency debt.

3.4 Debt Frontiers for Different Costs of Default

Figure 4: Debt Frontiers with Different Costs of Default ($\lambda = 0.02$ and $\lambda = 0.03$)

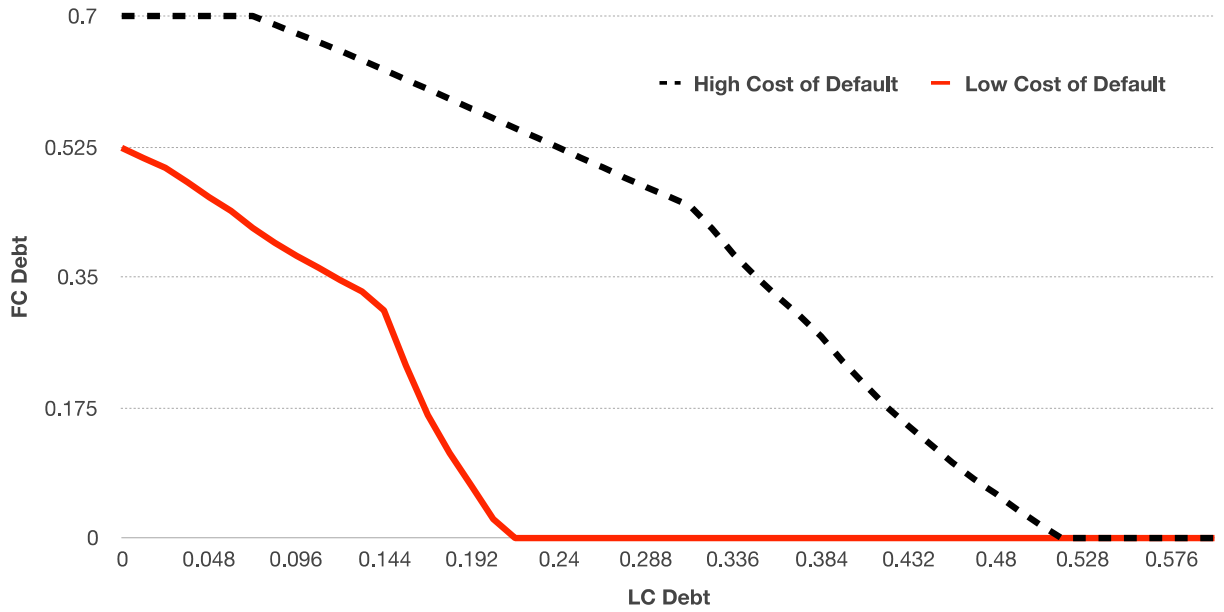


Figure 4 plots debt frontiers for two different values of cost of default ($\lambda = 0.02$ and $\lambda = 0.03$) with $\xi = 0.105$ and fixing other parameters at the benchmark values. For the low cost of default, the borrowing

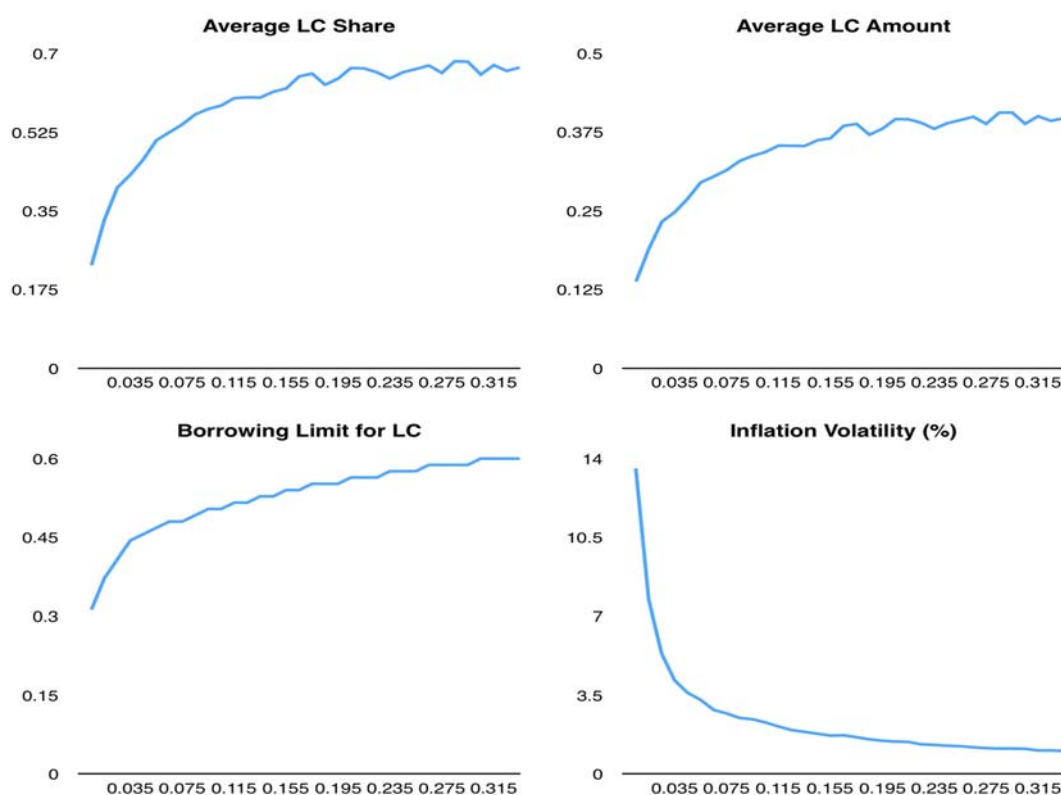
limits for local and foreign currency debt (solid red line) are much tighter than those for the high cost of default.

3.5 Sensitivity Analysis

This section conducts sensitivity analysis with respect to several key parameters to investigate the effects of changes in the key parameters on the optimal composition of sovereign debt.¹⁰ The main finding of this section is that even if the cost of inflation is the most important determinant for emerging economies' ability to borrow in local currency debt, there is *no* clear-cut link between the currency composition of external sovereign debt and inflation related variables. Both the currency composition of debt and inflation related variables are endogenous and, depending on changes in exogenous variables or different parameters, we can have either a positive or negative relationship between these variables.

Costs of Inflation

Figure 5: Sensitivity Analysis w.r.t Cost of Inflation



¹⁰ The Appendix contains plots of additional variables in response to variation in the model parameters: volatility of consumption; debt/GDP; correlation of inflation to GDP; s.d.(trade balance/Y)/s.d.(Y); correlation of trade balance/Y with Y; and, the correlation of inflation with consumption.

Figure 5 plots average shares of local currency debt, average local currency debt amounts, borrowing limits for the local currency debt \underline{B}^{loc} , and volatilities of inflation for different values of ξ from 0.005 through 0.335. As the cost of inflation increases, the economy can borrow more in local currency as shown in the increase in the borrowing limit for local currency debt (the left panel in the bottom). Accordingly, the average LC share and local currency debt amount increase. Moreover, the volatility of inflation decreases as the cost of inflation increases.

For a low range of ξ , we have a rapid and monotone increase in the average LC share, LC amount, and the borrowing limit for local currency debt as ξ increases. However, above a certain value of ξ , the increase in the average LC share and amount is not monotone in ξ , even though the borrowing limit for the local currency debt is monotonically increasing in ξ . That is because at a high value of ξ , a further increase in the cost of inflation makes the consumption smoothing ability of local currency debt worse off, as consumption smoothing using inflation is very costly. Moreover, the increase in ξ decreases both the values of the contract and debasement (see the proof of the proposition 3), but does not affect the value of default at all. Hence, for very high values of ξ , as ξ increases, the value of default becomes more likely to outweigh the values of the contract and debasement especially at states with a large amount of foreign currency debt. Therefore, it has more influence in determining the debt frontier, especially the maximum possible amount of foreign currency debt for any given b^{loc} , thus affecting the local currency share of sovereign debt, differently from the cases of a low range of ξ .

The predictions of the model in the figure 5 are consistent with two empirical facts regarding the “Original Sin” phenomenon: First, the emerging economies which suffered high inflation volatility during the 80s and 90s borrowed mainly in foreign currency. Second, the emerging economies which have gotten increasingly more disciplined in monetary policy are more likely to borrow in local currency during the last decade. That is, our model can predict both the “Original Sin” phenomenon for emerging economies in the 80s and 90s and a recent surge in local currency borrowings for the emerging economies with more disciplined monetary policy. In section 3.7, we document an increasing trend of the local currency share in sovereign debt for emerging economies after these countries have adopted inflation targeting, and this trend looks consistent with Figure 5.

Discount Factor

Figure 6: Sensitivity Analysis w.r.t Discount Factor

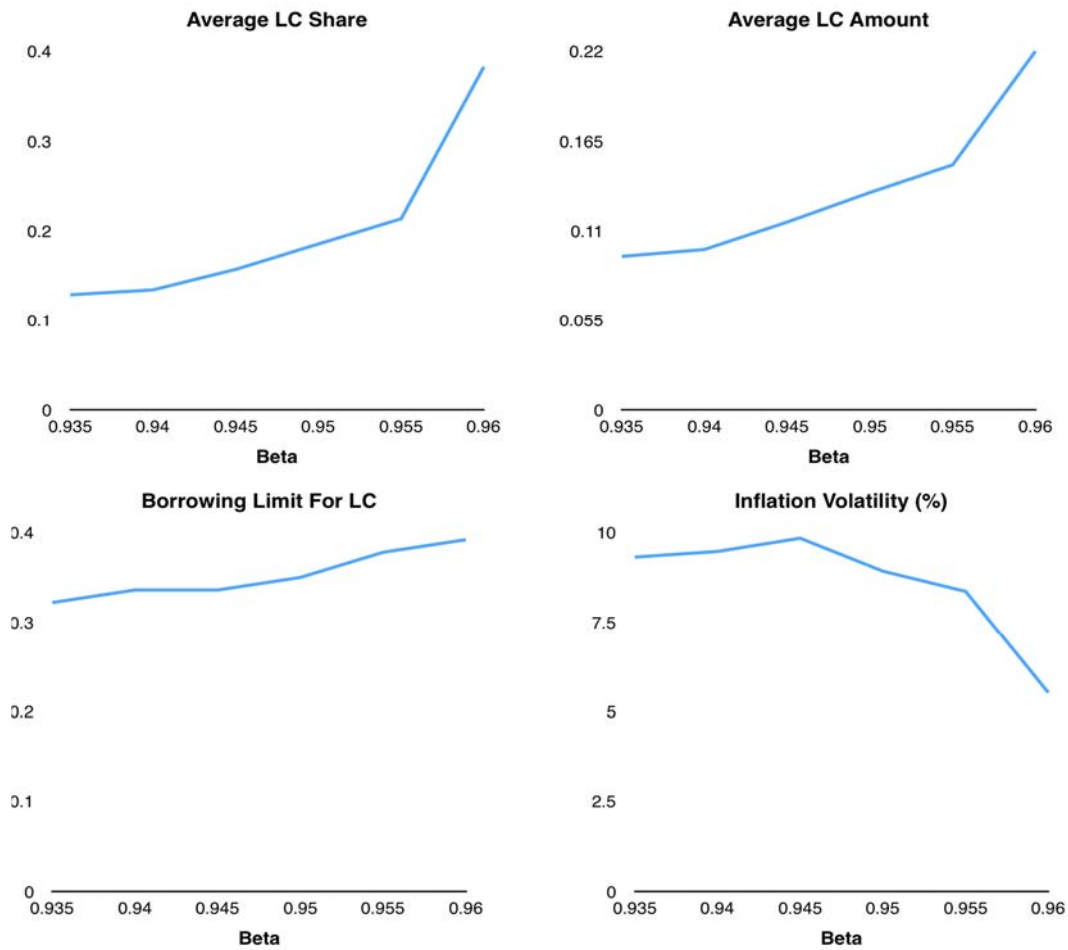


Figure 6 shows sensitivity analysis with respect to different values of the discount factor β from 0.935 to 0.96. As households in the economy become more patient, the government becomes less tempted to debase the currency or default on debt. Accordingly, the economy can and does borrow more in local currency. However, the volatility of inflation decreases as the discount factor increases.

Risk Aversion

Figure 7: Sensitivity Analysis w.r.t Gamma

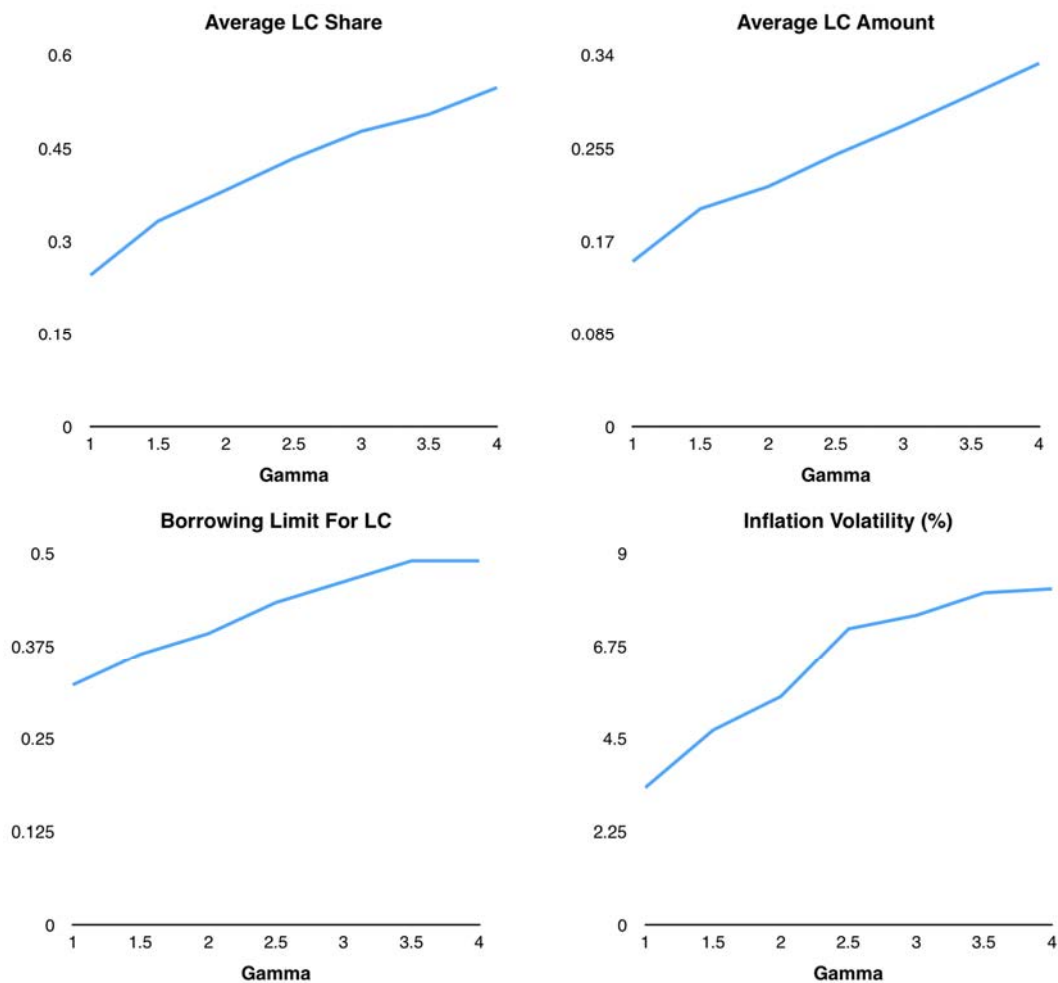


Figure 7 displays sensitivity analysis with respect to different values of γ . As households become more risk averse, it values consumption smoothing more, and thus prefer local currency debt. Hence, the borrowing limit for the local currency debt increases with γ . Even though the local currency share of debt increases, inflation volatility increases, which is different from the predictions for the cases of increasing ξ and β . As households get more risk-averse, the economy borrows more in local currency and more actively conducts monetary policy to smooth consumption, taking advantage of the state-contingent nature of local currency debt.

Output Cost of Default

Figure 8: Sensitivity Analysis w.r.t Output Cost of Default

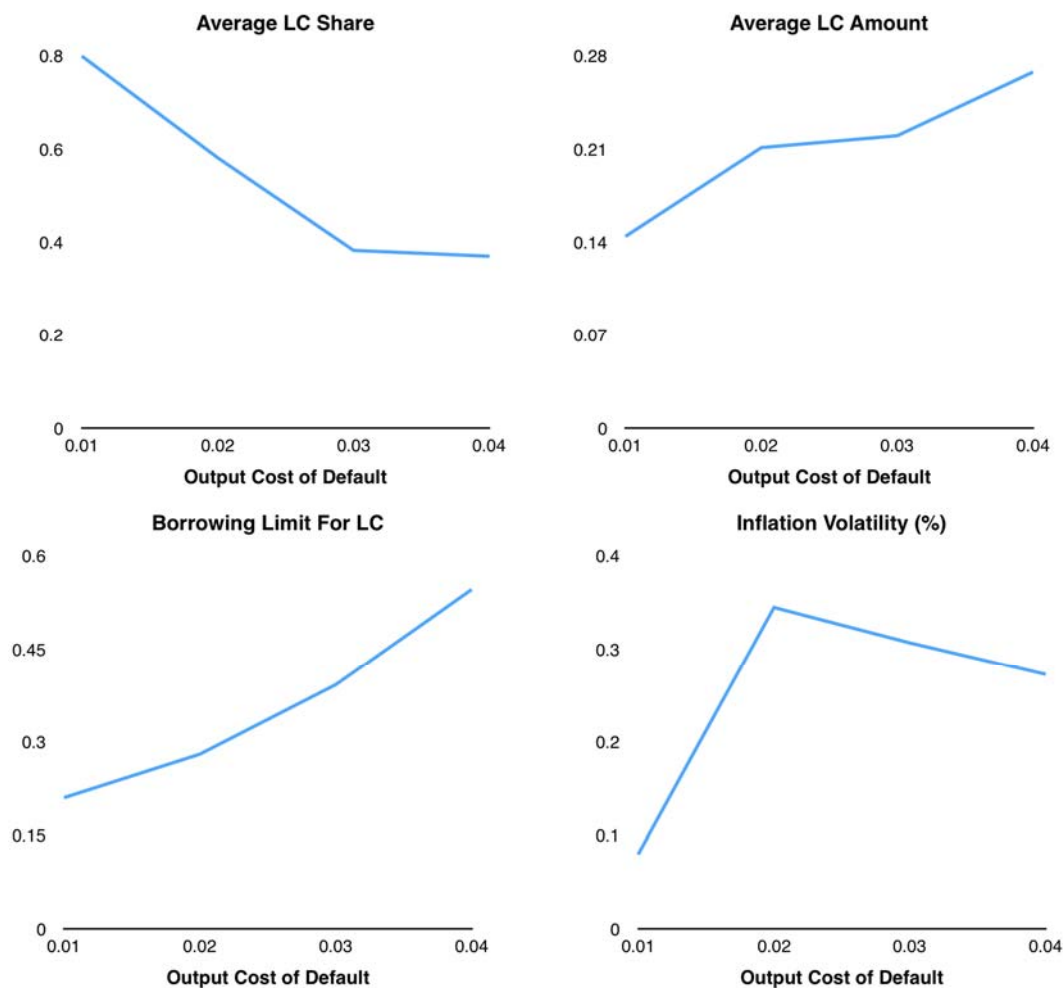


Figure 8 shows sensitivity analysis with respect to different output cost parameters, λ . As the output cost of default increases, the borrowing limit for local currency increases, and the economy borrows more in local currency. However, the average local currency share decreases with λ . The debt frontier enlarges as the output cost of default increases; however as shown in the figure 2, compared to the local currency debt, the borrowing limit for *foreign* currency debt gets more relaxed. The economy tends to borrow relatively more in foreign currency than in local currency, even if the *absolute* amount of local currency debt increases with λ .

Persistence of Income Shock

Figure 9: Sensitivity Analysis w.r.t Persistence of Income Shock

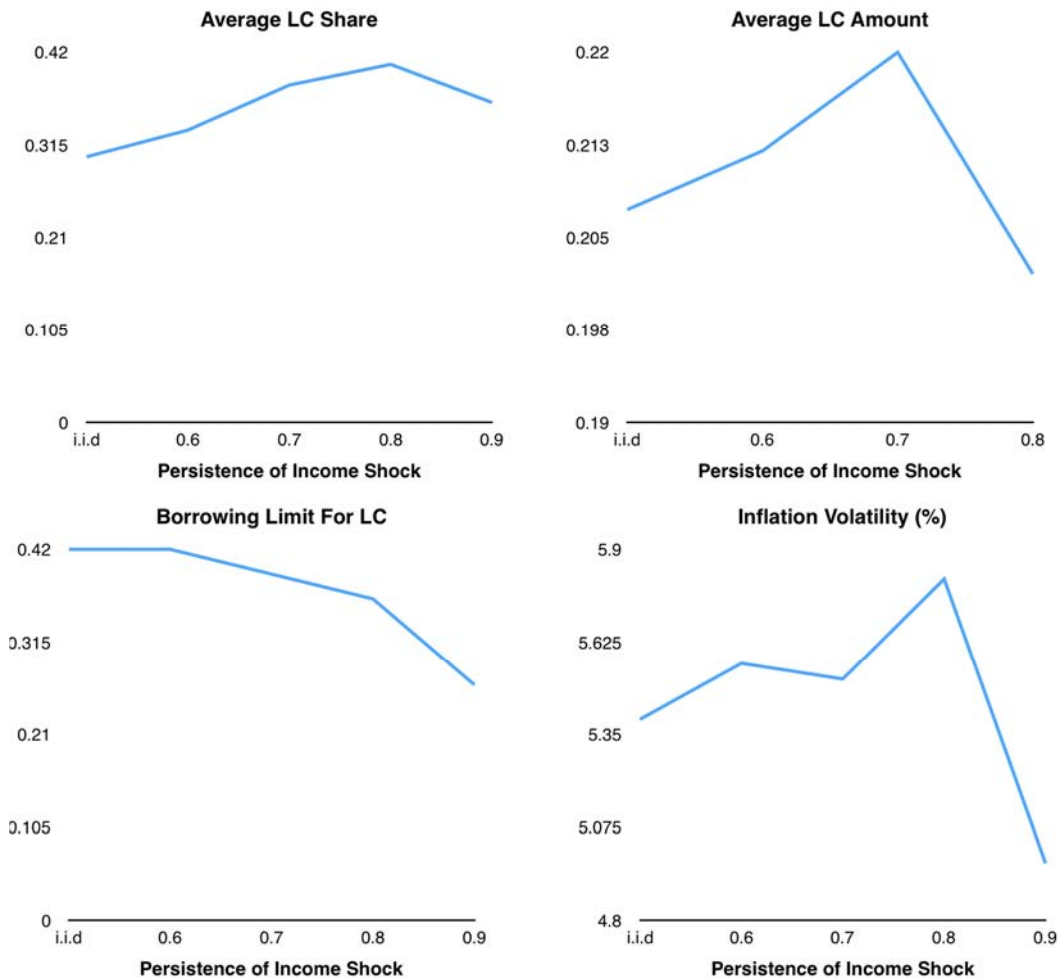


Figure 9 presents sensitivity analysis with respect to different degrees of persistence of the income shock process. As the income shock gets more persistent, the value of debasement/default increases; when a good income shock hits the economy, the good income shock is expected to persist for a long period of time, thus making breaching the contract more attractive. This is reflected in a decrease in the borrowing limit for the local currency debt with an increase in the degree of persistence. However, the average local currency share and amount of local currency debt shows a non-monotonic shape with respect to the degree of persistence.

Income Variance

Figure 10: Sensitivity Analysis w.r.t Income Variance

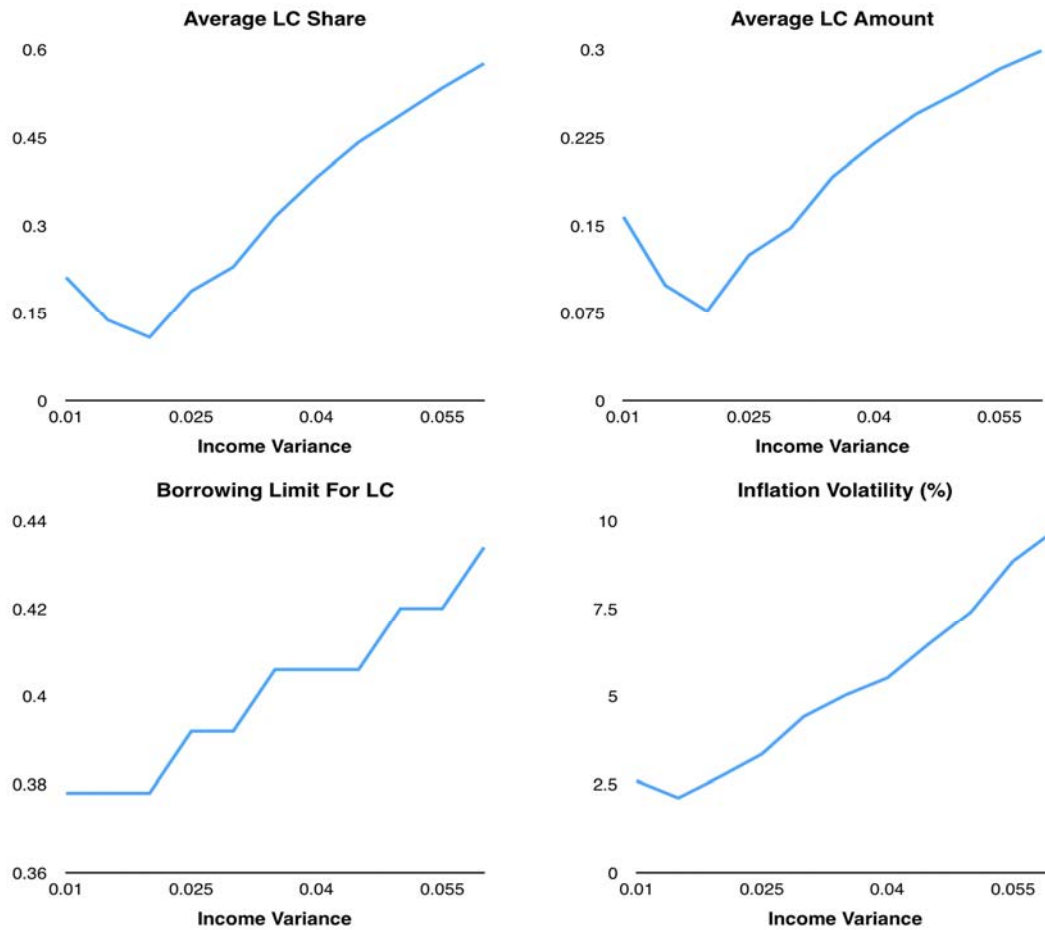


Figure 10 exhibits sensitivity analysis with respect to different levels of income variance. As the income variance increases, the value of breaching the contract decreases; the values of debasement and default decrease, because the economy has a less efficient consumption smoothing vehicle in the “Original Sin” regime and permanent autarky in the face of higher income volatility. As the income variance increases, the borrowing limit for local currency debt increases. The average local currency share and the amount of local currency debt show a U-shape in the income variance. Inflation volatility follows the shape of the average local currency share as the income variance increases.

3.6 Why Do We Still Have the Mystery of Original Sin?

In section 1.2, we find that there is still a “mystery of original sin”. The regression results show that there are no meaningful economic regressors except for the absolute size of a country to account for the Original Sin of emerging economies. However, the findings in the previous sensitivity analysis show why we might have weak empirical support for the hypothesis that monetary credibility and weak institutions of emerging economies are the main cause of Original Sin.

Table 7: Correlation between LC share and Inflation Volatility

Parameters	Correlation (LC share, Inflation Volatility)
Cost of Inflation	negative
Discount Factor	negative
Risk Aversion	positive
Output Cost of Default	non-monotonic
Persistence of Income Shock	positive
Volatility of Income Shock	positive

Table 7 summarizes the correlations between the LC share and inflation volatility in simulations with respect to changes in key parameters in our model. With respect to the change in parameters for cost of inflation and the discount factor, the LC share and inflation volatility move in the opposite direction. On the other hand, with respect to the change in parameters for the degree of risk-aversion, and persistence and volatility of income shock, the LC share and inflation volatility move in the same direction. With respect to the change in the parameter for the output cost of default, we do not see any monotonic relationship between the two variables.

Figure 11 shows two scatterplots of LC share and volatility of inflation and illustrates this point more clearly. The red lines in the left panel of Figure 11 show movements in (LC share, volatility of inflation) pairs for two different costs of inflation as income variance increases, fixing other parameters at the benchmark values. The pair moves toward the northeast as income variance increases. The blue dashed line shows movements in (LC share and volatility of inflation) pairs as the cost of inflation parameter ξ increases, fixing other parameters at the benchmark values. The pair moves toward the northwest as the cost of inflation increases. The red line in the right panel of Figure 11 tracks movements in (LC share and volatility of inflation) pairs as the degree of risk-aversion increases. The pair in the red line moves toward the northwest as the degree of risk-aversion increases. The blue dashed line in the right panel is the same as that in the left panel.

Figure 11: Scatterplots of Volatility of Inflation and LC Share

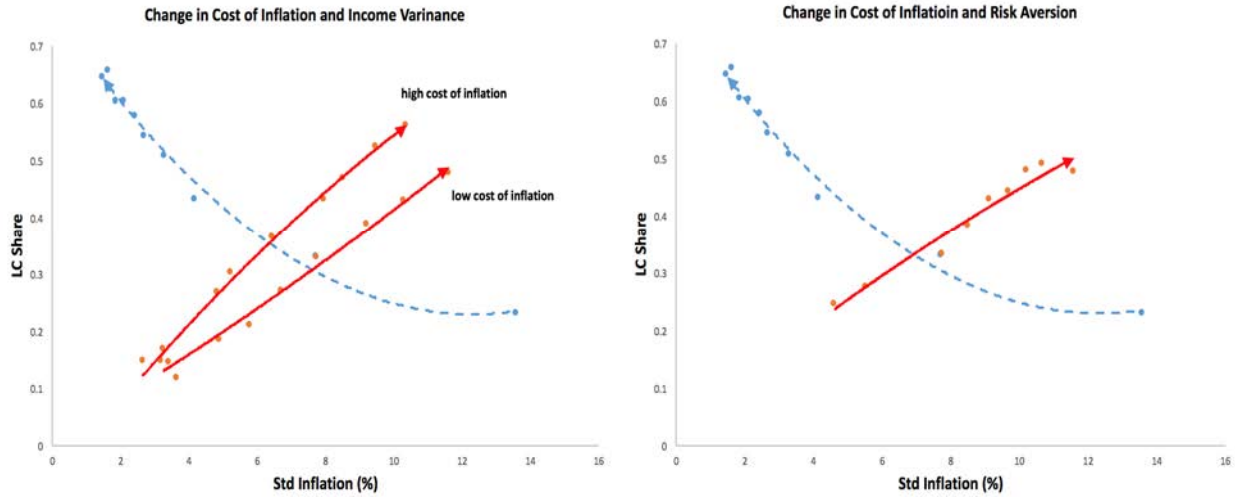


Figure 11 shows that even though emerging economies have been able to borrow more in local currency due to more disciplined monetary policy in the last decade, we can still have weak empirical support for the hypothesis that lack of monetary credibility is the root cause of Original Sin.

Our model predicts that the monetary credibility associated with the cost of inflation is the most important determinant for emerging economies' ability to borrow in local currency debt, but both inflation and the local currency share of external sovereign debt are endogenous variables, so that for countries with different characteristics (e.g., different degree of patience, risk-averseness, etc.), we observe a non-monotonic relationship between inflation and LC share in the data as shown in the Figure 1.

3.7 Inflation Targeting and Local-Currency Debt

Arslanalp and Tsuda (2014) provide calculations for the amount of externally-held government debt issued in local currency and total externally-held government debt for twenty-four emerging markets. The data are quarterly, for most countries beginning in 2004:I, and ending in 2015:IV for all countries.

As Du and Schreger (2016b) have noted, the share of sovereign debt denominated in local currency has risen substantially over this time period for many emerging markets. That trend is apparent for many of the countries in the Arslanalp-Tsuda data. In many cases, the share of debt in local currency went through a period of steady increase and the ratio appears to have settled permanently at a higher level.

Arslanalp and Tsuda report data on externally held foreign debt for twenty-four countries. We exclude five countries from our analysis here because missing data in the series make them too short to allow us to calculate the change in local-currency shares over the 2004-2015 period.¹¹ We exclude four other countries

¹¹ The countries we exclude on these grounds are Chile, Colombia, Latvia, Romania, and Uruguay.

– China, Egypt, India and Thailand – because the share of government debt that is held externally is small, being less than 10% of all government debt. Figure 12 plots these debt shares for the remaining fifteen countries.

The chart shows that many countries, such as Brazil and Mexico, have greatly increased the share of their externally held debt that is denominated in their own currency. Other countries, such as Argentina and the Ukraine, still denominate almost all foreign held debt in foreign currency.

Table 8 shows that many developing countries have changed their monetary policies since 2000, and adopted inflation targeting regimes.¹² In terms of our model, we interpret this change as evidence of a greater cost of inflation. The countries may have adopted an inflation-targeting rule because they have determined that the political cost of inflation is too high (especially when other emerging markets are seen to have brought their inflation rates under control.) Or it may be that it is politically costly to fail to meet an announced inflation targeting goal. In turn, we attribute the rise in the ability of these governments' ability to sell local-currency denominated debt abroad to this change toward inflation-targeting monetary policy. In accordance with our model, greater inflation costs support the ability to borrow internationally in local-currency debt.

In the early part of the sample, many countries borrowed abroad almost exclusively in foreign currency (generally, U.S. dollars.) Table 8 lists the share of debt denominated in local currency for each country in the quarter in which it was at a minimum. The table also shows the average level share of external debt in local currency over all of the quarters in the latter half of the sample, 2010-2015.

The three countries that never adopted inflation targeting – Argentina, Bulgaria and the Ukraine – remain in the original sin regime even through the end of the sample. In contrast, all but one of the countries that adopted inflation targeting saw their share of externally held debt increase to at least 35 percent in the 2010-2015 period.¹³ Lithuania is the exception, in that it did announce a policy of inflation targeting in 2004, but almost all of its externally held debt is denominated in foreign currency. However, Lithuania was on the path to adopting the euro, so it is not surprising that its foreign held debt was denominated in euros.

¹² See Ebeke and Fouejieu (2015).

¹³ Malaysia has not announced an inflation-targeting policy, but clearly has pursued such a policy. Since 2000, its average inflation has been only 1.7 percent on an annual basis, and the highest annual rate during that period was 3.7 percent. It experienced a sharp rise in the share of its external debt denominated in ringgit beginning in the first quarter of 2004.

Table 8**Inflation Targeting and Local-Currency Debt**

Country	Date inflation targeting announced	Minimum Share in Local Currency	Average Share in Local Currency 2010-2015	Change from Minimum to 2010-2015 Average
Argentina	never	0.00	0.04	0.04
Brazil	1999	0.06	0.76	0.70
Bulgaria	never	0.00	0.01	0.01
Hungary	2004	0.31	0.43	0.12
Indonesia	2005	0.34	0.52	0.18
Lithuania	2004	0.00	0.05	0.05
Malaysia	2000	0.21	0.92	0.71
Mexico	2001	0.09	0.70	0.61
Peru	2002	0.00	0.37	0.37
Philippines	2002	0.00	0.35	0.35
Poland	1998	0.32	0.48	0.16
Russia	2008	0.00	0.33	0.33
South Africa	2000	0.35	0.72	0.37
Turkey	2006	0.24	0.50	0.26
Ukraine	never	0.01	0.06	0.05

Figure 12

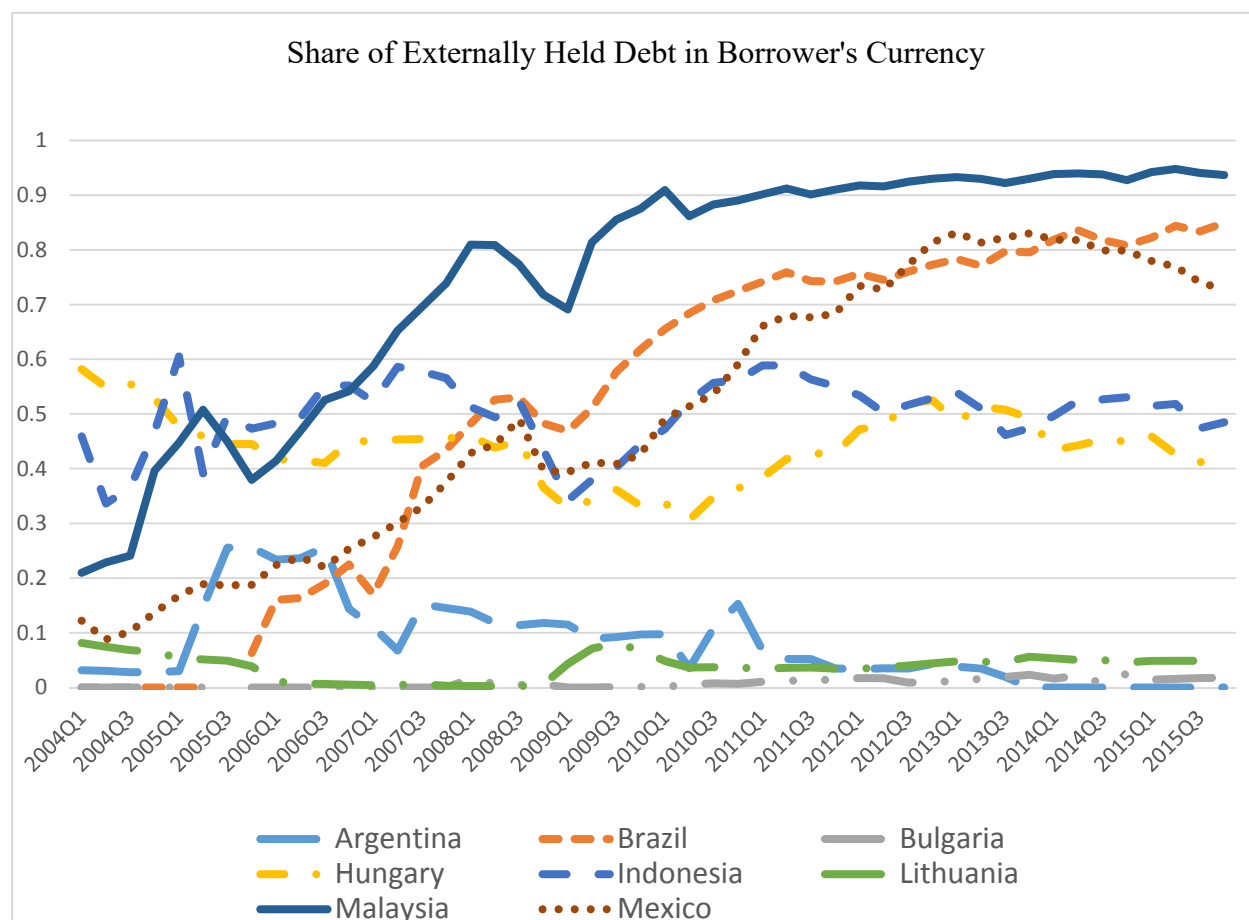
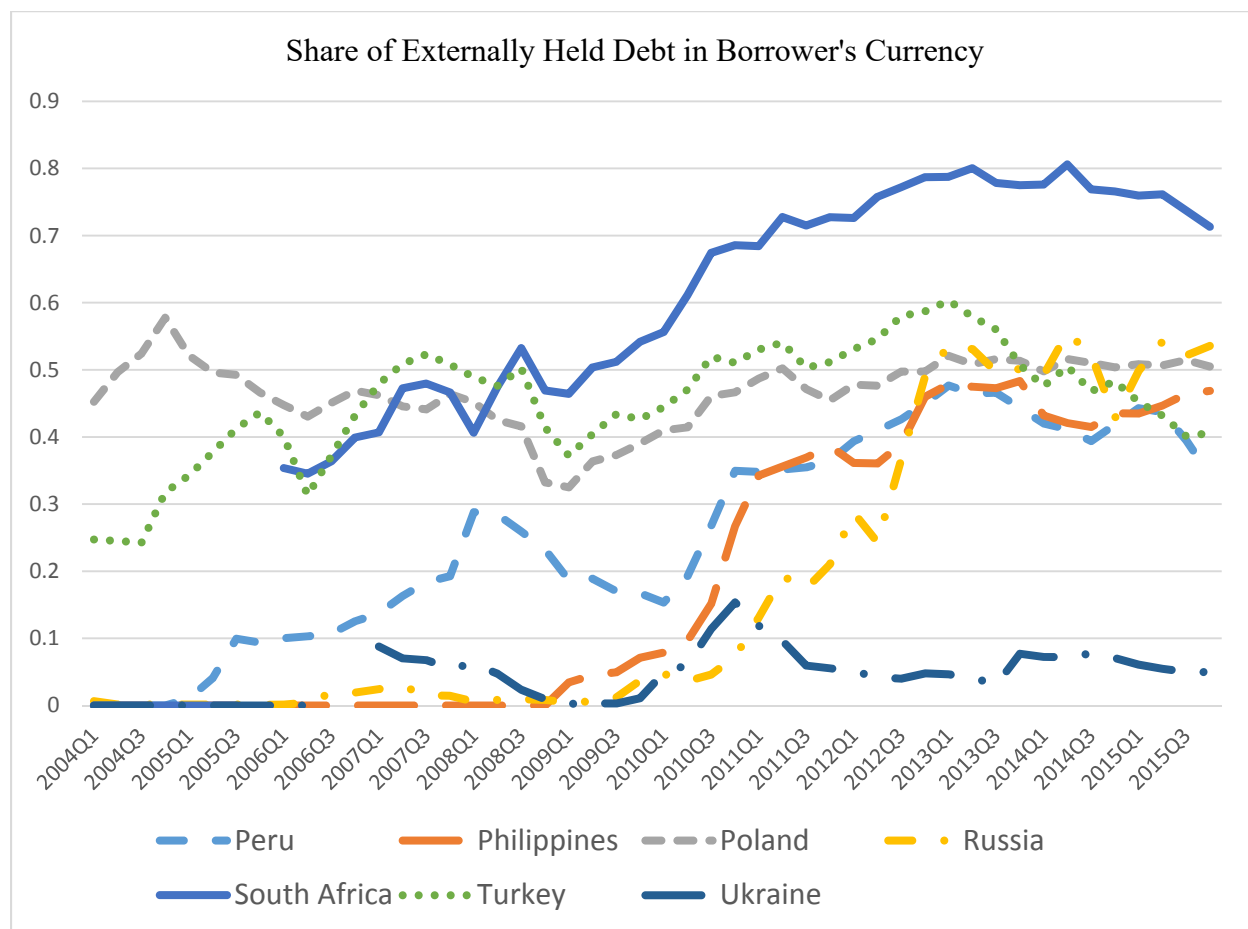


Figure 12 (continued)



3.8 Three Country Comparison Using Simulated Method of Moments

As we have noted, Figure 1 shows that there is very little discernible relationship between the inflation performance of emerging market sovereign debtors and the share of external debt denominated in domestic currency. In this section, we undertake an examination of three of those countries, Colombia, Indonesia, and Mexico. These countries are at comparable levels of development. We see from Figure 1 that a larger share of Indonesia's debt is denominated in domestic currency, but its overall inflation performance is worse than Colombia's. On the other hand, Mexico's LC share is as large as that of Indonesia, but Mexico's overall inflation performance is better than Indonesia. Table 9 presents some summary statistics for the three countries. All values in the table are averages over the sample period from 2004-2015.

What characteristics of each country account for the differences in the local currency share and inflation volatility across the three countries? To answer this question, we estimate the model for each country using simulated method of moments. Our objective in this section is to illustrate how our model can account for this pattern of external debt and inflation performance.

Table 9: Summary Statistics for Colombia, Indonesia, and Mexico

	Colombia	Indonesia	Mexico
Local Currency Share	29.26%	50.02%	50.49%
GDP per Capita	\$6,292.47	\$3,094.62	\$9,050.62
GDP (Current US Dollars)	\$263 billion	\$635 billion	\$1,062 trillion
Average Inflation	4.23%	7.06%	4.08%
Std inflation	1.60%	2.91%	0.71%
Max inflation	6.99%	13.11%	5.30%
Inflation Targeting (in the last decade or before)	Yes	Yes	Yes

Specifically, our objective is to see how our model can explain the local-currency shares of external sovereign debt – 29.26% for Colombia, 50.02% for Indonesia, 50.49% for Mexico – while simultaneously they have different volatilities of inflation- 1.60% for Colombia, 2.91% for Indonesia, and 0.71% for Mexico on an annual basis.).

We have three types of parameters for estimation. As common parameters, the annual risk-free rate r is set to be 4%, which is the standard value in the literature. The mean inflation $\bar{\pi}$ is normalized to be one. The two parameters related to the income process for each country- the mean and persistence of output – are estimated for each of these three countries directly from the data.¹⁴ That leaves us with four parameters – the cost of inflation ξ , the coefficient of risk aversion γ , the output cost of default λ , and the time discount factor β – that we estimate from the model to match the following four target moments: the standard deviation of inflation, LC share of external public debt, the external public debt to GDP ratio, and the ratio of the volatility of consumption to output. Table 10 lists these parameter values, and Table 11 reports the target and simulated moments for each country.

Table 10: Parameters

Common Parameter

Parameters	Values	Description
r_f	0.04	Risk Free Rate
$\bar{\pi}$	1	Mean Inflation (Normalization)

Parameters Estimated Directly from the Data

Parameters	Values			Description
	Colombia	Indonesia	Mexico	
ρ	0.79	0.76	0.66	Persistence of GDP
σ_ε	0.018	0.03	0.027	Volatility of GDP

¹⁴ We estimate using annual GDP data for the period 1960-2015 from the World Bank. We HP-filter the series with a smoothing parameter of 400 (annual frequency) and estimate the AR(1) process using the cyclical components of each series.

Parameters Estimated from the Model (SMM)

Parameters	Estimates			Target Moments
	Colombia	Indonesia	Mexico	Description
ξ (Cost of Inflation)	0.082	0.125	0.504	Std of Inflation
γ (Risk Aversion)	2.73	4.63	4.08	LC Share
λ (Output Cost of Default)	0.73%	0.85%	0.6%	External Public Debt to GDP
β (Time Discount Factor)	0.942	0.937	0.925	$\sigma(c)/\sigma(y)$

We undertake this exercise to illustrate how our model might be consistent with the “mystery of Original Sin” – the lack of relationship between the local-currency share of external foreign debt and measures of economic performance – and do not intend these estimates to be taken as earnest measures of the utility cost of inflation or the degree of risk aversion in each country. Our data series are too short to deliver precise estimates of these parameters, and our model is quite stripped down. Instead, we show how the determinants of original sin may be hidden in deep parameters. There may be many factors – especially political – that affect both the country’s perceived cost of inflation, and the risk aversion of households (or of the government acting on their behalf when it issues foreign debt.)

Table 11: Target and Simulated Moments

Description	Target Moments (Data)			Simulated Moments		
	Colombia	Indonesia	Mexico	Colombia	Indonesia	Mexico
Std of Inflation	1.61 %	2.91 %	0.71 %	1.62 %	2.93%	0.71%
LC Share	29.26%	50.02%	50.49%	29.13 %	50.93%	50.73%
External Public Debt to GDP	14.98%	18.23%	14.89%	15.29%	18.27%	14.57%
$\sigma(c)/\sigma(y)$	0.936	0.89	0.939	0.929	0.87	0.938

Table 10 shows that in the estimated model, Mexico has a very high cost of inflation so that Mexico's local currency share of external debt is high and its volatility of inflation is low. This prediction of the model regarding Mexico is consistent with Calvo (1978) in that a government's strategic debasement to inflate away the real value of debt can pose a significant obstacle to issuing local currency debt. Since the cost of debasement is too high for Mexico, it can borrow a significant amount of local currency debt and conduct a disciplined monetary policy.

On the other hand, Indonesia's volatility of inflation is higher than Colombia (2.91% in Indonesia vs. 1.60% in Colombia), but Indonesia's LC share is higher than Colombia in the data (50.02% in Indonesia vs. 29.26% in Colombia). This fact has so far puzzled economists as this seems to suggest that debasement risk has little to do with the ability of emerging economies to borrow in local currency. However, our estimated parameters show why we observe these puzzling facts called "mystery of Original Sin". Indonesia has a higher cost of inflation and is more risk-averse than Colombia. Indonesia is more credible in terms of monetary policy, so it can borrow more in local currency than Colombia. But Indonesia is more risk averse, so that it uses the monetary policy more actively to smooth its consumption, thus leading to a higher volatility of inflation as shown in the sensitivity analysis in section 3.7.

Table 12: Other Moments of Data and Model

Description	Data Moments			Simulated Moments		
	Colombia	Indonesia	Mexico	Colombia	Indonesia	Mexico
Corr (LC Share, GDP)	0.45	0.40	0.92	0.71	0.81	0.91
Corr(C, GDP)	0.998	0.99	0.99	0.98	0.96	0.99
Corr(π , GDP)	-0.69	-0.58	-0.42	-0.61	-0.64	-0.75
Corr(π , C)	-0.69	-0.58	-0.43	-0.51	-0.49	-0.67
Corr(TB/y, y)	-0.18	-0.86	0.36	0.41	0.55	0.45
σ (TB/y)	2.10%	2.13%	0.40%	1.08%	1.30 %	0.51%

Table 12 compares data moments which are *not* targeted from the SMM to the simulated moments. Our model also well accounts for these empirical moments. Except for the correlation between trade balance and GDP,¹⁵ the model’s moments are very well consistent with empirical moments. In particular, we point to three features of the data that are well-captured by our model. In all three countries, inflation is strongly negatively correlated with output and with consumption. Our model replicates those correlations quite closely, even though those moments were not targeted. Also, our model can capture the observed procyclicality of the local currency share of debt, which has been noted by Ottonello and Perez (2016) and addressed in that study with a different model.

4. Model with Phillips Curve

In this section, we consider a simple but important extension of the basic model. In the model we have examined heretofore, the stabilizing properties of monetary policy work only through their effects on required payments on local-currency denominated debt. As we have shown, countries that are able to escape original sin can smooth consumption to some extent by using inflation/currency depreciation during periods of low output in order to reduce the real value of their debt service.

There is, of course, another channel through which monetary policy might smooth fluctuations that has a long tradition in macroeconomics – in Keynesian models when nominal prices do not adjust instantaneously, policy can induce higher real output at the cost of higher inflation. We introduce a simple “expectational Phillips curve” in which actual output can deviate from “potential” output if realized inflation turns out to be different than expected inflation. In this simple set-up, potential output is exogenously given and follows a stochastic process like the one assumed previously in this study for actual output. Now, actual output can rise above (fall below) potential output when actual inflation is greater than (less than) the rationally-expected rate of inflation.

Even with the introduction of the Phillips curve, we still assume that monetary policymakers have no inherent ability to commit to an inflation plan. There is an extensive literature that has emphasized the relative ineffectiveness of monetary policy in stabilizing output or consumption when policymakers can act only under discretion. Much of the New Keynesian optimal monetary policy literature either assumes policymakers have the ability to act under commitment, or else contrasts the effects of policy under commitment versus discretion. Usually those studies take the ability or inability to commit to a monetary policy plan as exogenously given in the model.

¹⁵ Our model does not match counter-cyclical trade balance for Colombia and Indonesia. It must be, however, noted that our endowment economy model abstracts from investment, which is key to generating counter-cyclicality of the trade balance for small open economy models.

It is well known that there is an inflationary bias when monetary policy is set without commitment.¹⁶ Rogoff (1985) proposes solving this problem by appointing a central banker that puts relatively more weight on inflation stabilization than the social objective function calls for. Walsh (1995) suggests that central bankers are able to commit to monetary policy rules if they can sign contracts in which the central bankers' rewards are tied to the rate of inflation. We find here a different motivation for at least partial commitment. A country that is able to borrow in local currency engages in a contract with international lenders that specifies state-dependent inflation rates. This contract, then, commits the policymaker to a "rule" for inflation, with a punishment that the country falls into the original sin regime if the rule is violated. The ability to borrow in local currency not only allows the country to smooth consumption by making the real value of debt repayment state dependent, but it also allows the policymaker to exploit the Phillips curve to a greater extent. Countries that can only borrow in foreign currency or are autarkic can only set monetary policy without any ability to commit. We will show here that the ability to use the Phillips curve as another tool to smooth consumption confers additional welfare gains for countries that receive a contract to borrow in their own currency.

4.1. Setup of the Extended Model

Phillips Curve

We use the following Phillips curve:

$$z_t(\pi_t, \pi_e) = (1 + \delta(\pi_t - \pi_e))y_t, \quad (30)$$

where z_t is actual output at period t , π_t is the inflation rate at period t , and π_e is the rational expectation of π_t formed at the end of period $t-1$ by agents in this economy, before π_t is determined at period t . Finally, δ is assumed to be nonnegative, and y_t is potential output at period t , which follows the same Markov process as in the benchmark model in the section 2. The government in this economy can achieve higher output than potential output y_t if it chooses π_t above π_e , but this will incur the cost of inflation. Other than this Phillips curve, all other assumptions in this model are identical to those in the benchmark model in section 2.

Value of Default

The value of default is given by

¹⁶ See Woodford (2003), chapter 7, for an extensive discussion.

$$V^{def}(y_{t-1}, y_t) = \max_{\pi_t} [u(c_t) - C(\pi_t - \bar{\pi})] + \beta E_t V^{def}(y_{t+1}), \quad (31)$$

subject to

$$c_t = h(z_t(\pi_e, \pi_t)). \quad (32)$$

Unlike the benchmark model, the government in the economy in default conducts monetary policy to maximize the welfare of the economy by choosing π_t taking π_e as given. But, as with the benchmark model, the government does not have any inherent ability to commit to a monetary policy. In this case the government must conduct a *discretionary* monetary rather than the committed monetary policy. Finally, rational expectations of π_t implies:

$$\pi_e = E_{t-1}[\pi_t] \quad (33)$$

Value of Foreign Currency Borrowing (Original Sin Regime)

The value of foreign currency borrowing is given by

$$V^{for}(b_t^{for}, y_{t-1}, y_t) = \max_{\pi_t, b_{t+1}^{for}} [u(c_t) - C(\pi_t - \bar{\pi})] + \beta E_t [V^{for}(b_{t+1}^{for}, y_{t+1})], \quad (34)$$

subject to

$$c_t = z_t(\pi_t, \pi_e) + R^* b_t^{for} - b_{t+1}^{for} \quad (35)$$

$$\pi_e = E_{t-1}[\pi_t] \quad (36)$$

$$V^{for}(b_{t+1}^{for}, y_t, y_{t+1}) \geq V^{def}(y_t, y_{t+1}) \quad \text{for all } y_{t+1} \quad (37)$$

$$b_{t+1}^{for} \geq -D \quad (38)$$

As with the case of default, the government *cannot* commit to any monetary policy so that it must use a discretionary monetary policy. Unlike our baseline model, the government now chooses π_t in addition to b_{t+1}^{for} so as to maximize the social welfare of the economy under the Original Sin regime.

Values of Debasement and Contract

For the values of debasement and the contract, we have the same setup as in our basic model except that y_t is replaced with $z_t(\pi_t, \pi_e)$ in the budget constraint, and we have the rational expectations condition for π_e . For the case of strategic debasement, when the government deviates from the contracted inflation rate, it takes into account the Phillips curve effect as well as the reduction of real value of local currency debt.

As for the value of the contract, however, the government has now an additional consumption smoothing tool besides the one working through change in the real value of local currency debt. Moreover, the government now can conduct a committed monetary policy by following the optimal contract offered by the foreign lenders, even though it is constrained to a certain extent. Hence, foreign lenders in this case double as a commitment device who can punish the government for the deviation from the monetary policy specified in the contract. That is, by signing a local currency contract, the government not only escapes from the Original Sin regime, but also obtains the commitment device which enables it to conduct a committed monetary policy. Later in this section, we isolate this value of the commitment device for different values of δ .

4.2. Model Moments

Table 13 :Parameters for the Model with the Phillips Curve

Parameter	Value	Description
γ	3.81	Risk aversion
β	0.933	Time Discount Factor
r^*	4%	Risk Free Rate
ϵ	0.025	Std of Income
ξ	0.237	Cost of Inflation
λ	0.72%	Default Cost
ρ	0.74	Persistence of Income
δ	different values	Effect of Phillips curve

Table 13 lists the baseline parameters for the model with the Phillips curve. As baseline parameters, we use an average of the sets of the parameters estimated for the three countries in section 3.8. However, we

use different values of δ to see the effects of the Phillips curve. Table 14 compares several model moments for different values of δ . $\delta = 0$ refers to our basic model without the Phillips curve.

As δ increases, the Phillips curve gets steeper, so that the government can more easily increase actual output z_t above potential output y_t by choosing π_t higher than π_e . When the government *cannot* commit to any monetary policy, the steeper Phillips curve provides the government with more temptation to re-optimize or reset its monetary policy. This, in turn, leads to an increase in average inflation rates in equilibrium as agents rationally expect the government's temptation to re-optimize its monetary policy.

Table 14: Model Moments

	$\delta = 0$	$\delta = 0.2$	$\delta = 0.6$	$\delta = 1.0$
Average Inflation Rate for the Original Sin Regime	0%	4.09 %	12.28%	20.48%
\underline{B}^{loc} (% of GDP)	17.6%	20.8%	25.6%	41.0%
Average LC Share (%)	64.3%	62.9%	47.7%	20.69%
$\sigma(\pi_t)$	1.67%	1.81%	2.19%	2.58%
$\sigma(c_t) / \sigma(y_t)$	84.78%	83.26%	75.85%	74.43%
Debt to GDP ratio	18.18%	18.97%	27.36%	43.99%

The first row in the table 14 shows that the average inflation rate for the Original Sin regime increases as δ increases. At the same time, the value of the Original Sin regime decreases due to the high cost of inflation. That is, as δ increases, social welfare for the Original Sin regime, for which the government cannot commit, decreases. This result is consistent with Kydland and Prescott (1977) and Barro and Gordon (1983). This represents the well-known inflation bias when policy is set under discretion. As δ increases, the policymaker is more tempted to resort to inflation, for which the economy bears a cost.

Even if an increase in δ leads to a higher output gain at the time of strategic debasement, the value of debasement, on net, decreases, as the decrease in the value of Original Sin Regime (i.e., the continuation value for the value of debasement) outweighs the output gain at the time of debasement. Hence, as δ increases, the value of the contract increases relative to the value of debasement, so that the debt frontier is enlarged. We can see this from the increase in the maximum local currency borrowing \underline{B}^{loc} and the debt to GDP ratio with δ in the table 14.

For the case in which there is a local-currency debt contract, the gains from monetary policy's exploitation of the Phillips curve tend to outweigh those coming through changes in the real value of local currency debt as δ increases. The government more actively uses the monetary policy and relies less on local currency debt. The table shows this as the standard deviation of π_t increases and the local-currency share of debt decreases as δ rises.

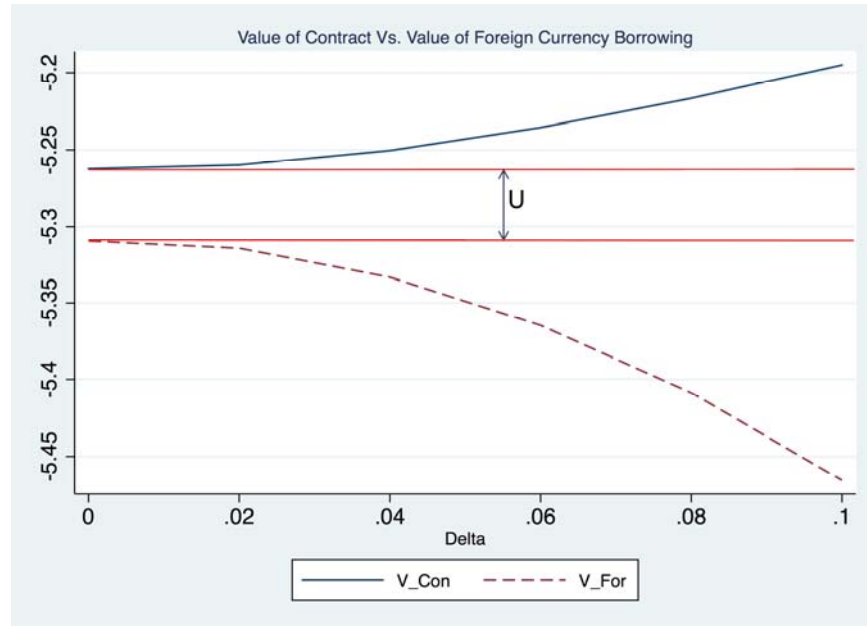
4.3. Value of Commitment Device

Figure 13 plots the value of contract $W(b_0^{loc}, b_0^{for}, y_0)$ and the value of foreign currency borrowing, $W^{for}(b_0^{for}, y_0)$ ¹⁷, where $b_0^{loc} = b_0^{for} = 0, y_0 = 1$ for the range of δ from 0 to 0.1. Let U be the difference between $W(b_0^{loc}, b_0^{for}, y_0)$ and $W^{for}(b_0^{for}, y_0)$ for the case of δ being zero. Then U represents the economy's welfare gain for obtaining the ability to borrow in local currency as the economy escapes from the Original Sin regime. For positive values of δ , the gap between the two value functions is the sum of two welfare gains; the first is the welfare gain for the ability to borrow in local currency represented by U , and the second is that for obtaining the commitment device which enables the government to conduct a committed monetary policy. The figure shows that the value of the commitment device increases as δ increases for the range of δ from zero to 0.1.

This diagram illustrates how the local-currency debt contract can work in a vein similar to the commitment devices introduced by Rogoff (1985) and Walsh (1995). Countries that can successfully obtain contracts – either, as we have noted in the baseline model, because they face high internal costs of excessive inflation, or because they greatly value the ability to smooth consumption – get a bonus, because the contract also confers a greater ability to utilize the Phillips curve to smooth output fluctuations.

¹⁷ $W^{for}(b_0^{for}, y_0) \equiv E_0[V^{for}(b_0^{for}, y_0, y_1)]$

Figure 13: Value of Contract Vs. Value of Foreign Currency Borrowing



5. Conclusions

This paper quantitatively investigates the currency composition of sovereign debt in the presence of two types of limited enforcement problems arising from a government's monetary and debt policy: strategic currency debasement and default on sovereign debt. Local currency debt has better state contingency than foreign currency debt in the sense that its real value can be changed by a government's monetary policy, thus acting as a better consumption hedge against income shocks. However, this higher degree of state contingency for local currency debt provides a government with more temptation to deviate from disciplined monetary policy, thus restricting borrowing in local currency more than in foreign currency. The two financial frictions related to the two limited enforcement problems combine to generate an endogenous debt frontier for local and foreign currency debt. Our model predicts that a less disciplined country in terms of monetary policy borrows mainly in foreign currency, as the country faces a much tighter borrowing limit for the local currency debt than for the foreign currency debt. The prediction of our model is consistent with the "Original Sin" phenomenon and can also account for a surge in local currency borrowing by emerging economies in the recent decades. Additionally, the extension of our model to include a Phillips curve shows that the threat of losing the ability to borrow in local currency can foster monetary policy credibility.

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Appendix 1: Proof of the Propositions

Proposition 1: Suppose that there is no enforcement constraint (equation (21)) and that there is no cost of inflation (i.e., $C(\pi_t - \bar{\pi}) = 0$ for all π_t .) Then the optimal contract for interior solutions is such that

$$c(x_t^i) = c(x_t^j) \text{ for any } i \neq j.$$

Proof. The envelope condition for V^c with respect to $\pi_t(x_t^i)$ is given by

$$V_{\pi_t}^c = -u'(c(x_t^i)) \frac{i_t b_t^{loc}}{\pi_t(x_t^i)^2} \text{ for all } i.$$

The Lagrangean for the maximization problem is given by

$$L = \max_{\pi_t(x_t^i)} \sum_{y_t \in Y} \Pr(y_t | y_{t-1}) V^c(x_t^i; \pi_t(x_t^i)) + \lambda \left\{ \sum_{y_t \in Y} \Pr(y_t | y_{t-1}) \frac{i_t}{\pi_t(x_t^i)} - R^* \right\}$$

The first order condition w.r.t $\pi_t(x_t^i)$ is given by

$$\Pr(y_t^i | y_{t-1}) V_{\pi_t}^c(x_t^i) - \lambda \Pr(y_t^i | y_{t-1}) \frac{1}{\pi_t(x_t^i)^2} = 0$$

It follows that

$$V_{\pi_t}^c(x_t^i) \pi_t(x_t^i)^2 = V_{\pi_t}^c(x_t^j) \pi_t(x_t^j)^2$$

Combining the first order conditions and the envelope condition, we have:

$$u'(c(x_t^i)) i_t b_t^{loc} = u'(c(x_t^j)) i_t b_t^{loc}$$

Since $b_t^{loc} \neq 0$, we have the desired result:

$$u'(c(x_t^i)) = u'(c(x_t^j)) \text{ for any } i \neq j.$$

Definition 1: If $\underline{b}^{loc}(y) = 0$ and $\underline{b}^{for}(0, y) < 0$ for all $y \in Y$ in equilibrium, the model economy is in the “Original Sin” Regime.

Proposition 2: For sufficiently low values of β , for which the value of foreign currency borrowing exists, the model economy is in the “Original Sin” Regime..

Proof : We will show that for a sufficiently small amount of local-currency debt $b^{loc} < 0$, there exists a threshold β' such that for any $\beta < \beta'$, the value of contract is lower than the value of debasement, so that there is *no* available local currency contract.

First, consider a case in which the output cost of default is sufficiently high so that there exists $b^{for} < 0$ such that $V^{for}(b^{for}, y) \geq V^{def}(y)$ for all $y \in Y$ even for $\beta = 0$. That is, for any values of β , the value of foreign currency borrowing exists. $h(y_t) = 0$ for all y_t is one example.

For any given y_t and a sufficiently small amount of local-currency debt $\epsilon^{loc} < 0$ such that

$$V^{debase}(0, \epsilon^{loc}, y_t, y_{t+1}; \beta) > V^{def}(y_{t+1}) \text{ for all } y_{t+1} \text{ and all } \beta,$$

$$\text{let } f(\beta; \epsilon^{loc}, y_t) \equiv \min_{y_{t+1}} \left\{ V^c(0, \epsilon^{loc}, y_t, y_{t+1}; \beta) - V^{debase}(0, \epsilon^{loc}, y_t, y_{t+1}; \beta) \right\}.$$

It is straightforward that when $\beta = 0$, $\left\{ V^c(0, \epsilon^{loc}, y_t, y_{t+1}; \beta) - V^{debase}(0, \epsilon^{loc}, y_t, y_{t+1}; \beta) \right\} < 0$ for all y_{t+1} . That is, when the discount factor β is zero, the value of debasement is strictly larger than the value of contract. Hence, $f(0; \epsilon^{loc}, y_t) < 0$ when $\beta = 0$. For any discount factor sufficiently close to one but less than one, denoted by β^H , we have either of the following two cases.

Case (1): $f(\beta^H; \epsilon^{loc}, y_t) > 0$. Since $f(\cdot)$ is continuous in β , it follows from the intermediate value theorem that there exists $0 < \beta' < \beta^H$ such that $f(\beta'; \epsilon^{loc}, y_t) = 0$. Moreover, at the point $(\epsilon^{loc}, y_t, y_{t+1}^*, \beta')$ where $V^c(0, \epsilon^{loc}, y_t, y_{t+1}^*; \beta') = V^{debase}(0, \epsilon^{loc}, y_t, y_{t+1}^*; \beta')$, it follows from the envelope conditions for the values of contract and debasement w.r.t β that

$$f_{\beta}(\beta'; \epsilon^{loc}, y_t) = V_{\beta}^c - V_{\beta}^{debase} = E_t V^c - E_t V^{for} > 0$$

Since $\left[u(c_t^{debase}) - C(\pi_t^{debase}) \right] - \left[u(c_t^{con}) - C(\pi_t^{con}) \right] > 0$, we have that $E_t V^c - E_t V^{for} > 0$ at this point. This implies that at β' for which the values of contract and the value of debasement are equalized, an increase in β at β' increases V^c more than V^{debase} . Moreover, this implies that $f(\beta; \epsilon^{loc}, y_t)$ crosses the β axis only once. Hence, there exists β' such that for any $0 < \beta < \beta'$, $f(\beta; \epsilon^{loc}, y_t) < 0$. That is, for ϵ^{loc} and y_t , there exists a discount factor for which there is *no* available local currency contract so that the economy must borrow only in foreign currency.

Case (2): $f(\beta^H; \epsilon^{loc}, y_t) \leq 0$. In this case, we cannot use the intermediate value theorem. However, suppose that there exists $0 < \beta^* < \beta^H$ such that $f(\beta^*; \epsilon^{loc}, y_t) = 0$. However, as shown in the case (1), at the point for which $f(\beta^*; \epsilon^{loc}, y_t) = 0$, we have that $f_\beta(\beta^*; \epsilon^{loc}, y_t) > 0$. This implies that if $f(\beta = 0; \epsilon^{loc}, y_t) < 0$ and $f(\beta^H; \epsilon^{loc}, y_t) \leq 0$, there exists no $0 < \beta^* < \beta^H$ such that $f(\beta^*; \epsilon^{loc}, y_t) = 0$ because of the single crossing property. In this case, the value of debasement is larger than the value of contract all over β' s for $\epsilon^{loc} < 0$ and y_t .

Proposition 3: Suppose that the cost of the inflation function $C(\pi_t - \bar{\pi}; \xi)$ is differentiable with respect to ξ , and that $C(\pi_t - \bar{\pi}; \xi)$ is strictly increasing and convex in ξ for any given π_t . Moreover, suppose that for any given y_t and y_{t+1} , $V^{debase}(0, \underline{B}^{loc,L}, y_t, y_{t+1}; \xi^L)$ is sufficiently larger than $V^{def}(y_{t+1})$ (i.e., the equality in equation (26) holds with the value of debasement.) Then $\underline{B}^{loc,H} \leq \underline{B}^{loc,L}$ for $\xi^H > \xi^L$.

Proof: The envelope conditions for the values of debasement and contract w.r.t b^{loc} are respectively

$$V_{b^{loc}}^c = u'(c_t^{con}) \frac{i_t}{\pi_t^{con}} \text{ and } V_{b^{loc}}^{debase} = u'(c_t^{debase}) \frac{i_t}{\pi_t^{debase}}. \text{ Since } \pi_t^{debase} \geq \pi_t^{con} \text{ and } c_t^{con} \leq c_t^{debase}, \text{ we}$$

have that $V_{b^{loc}}^c \geq V_{b^{loc}}^{debase}$. That is, an increase in b_t^{loc} leads to an increase in both value functions, but V^c increases more than V^{debase} with b_t^{loc} .

On the other hand, the envelope conditions for the values of debasement V^{debase} and contract V^{con} w.r.t ξ are respectively $-C_\xi(\pi_t^{debase})$ and $-C_\xi(\pi_t^{con})$, where $C_\xi(\cdot)$ denotes a partial derivative w.r.t ξ . Since $C(\pi_t; \xi)$ is convex in ξ and $\pi_t^{debase} > \pi_t^{con}$, we have the following inequality:

$$V_\xi^{debase}(0, b^{loc}, y_t, y_{t+1}) = -C_\xi(\pi_t^{debase}) < -C_\xi(\pi_t^{con}) = V_\xi^{con}(0, b^{loc}, y_t, y_{t+1})$$

That is, an increase in ξ leads to a decrease in both value functions, but V^{debase} decreases more than V^{con} with ξ .

For any y_t and y_{t+1} , we have that

$$V^c(0, \underline{B}^{loc,L}, y_t, y_{t+1}; \xi^L) \geq V^{debase}(0, \underline{B}^{loc,L}, y_t, y_{t+1}; \xi^L).$$

For some y_t and y_{t+1} , equality holds in this inequality.

If we increase ξ at ξ^L , it follows from the Envelope condition w.r.t ξ , the gap between the values of contract and debasement ($V^c - V^{debase}$) gets larger. Then it follows from the envelope conditions w.r.t b^{loc} that there exists b^{loc} such that $b^{loc} \leq \underline{B}^{loc,L}$ and satisfies equation (26). Then we have that $\underline{B}^{loc,H} \leq \underline{B}^{loc,L}$ for $\xi^H > \xi^L$.

Proposition 5: *If $C(\pi_t - \bar{\pi}) = \infty$ for any $\pi_t \neq \bar{\pi}$, then $\pi_t(s^t) = \bar{\pi}$ for all t . Moreover, the currency composition between foreign and local currency debts is indeterminate.*

Proof: The proof is straightforward. If any deviation of inflation π_t from the target inflation rate $\bar{\pi}$ incurs an infinitely high cost of inflation, we have that $\pi_t(s^t) = \bar{\pi}$ in equilibrium. With the equilibrium inflation being $\bar{\pi}$ at any state of the world, the nominal interest rate on local currency debt i_{t+1} becomes $\bar{\pi}R^*$ at any state of the world from the lender's expected zero profit condition. Moreover, the real interest rate on the local currency debt is R^* at any state of the world. Then, the local and foreign currency debt become identical, so we have an indeterminate currency composition of the sovereign debt in equilibrium.

Additional Figures

Figure 5 Addendum: Sensitivity Analysis w.r.t Cost of Inflation

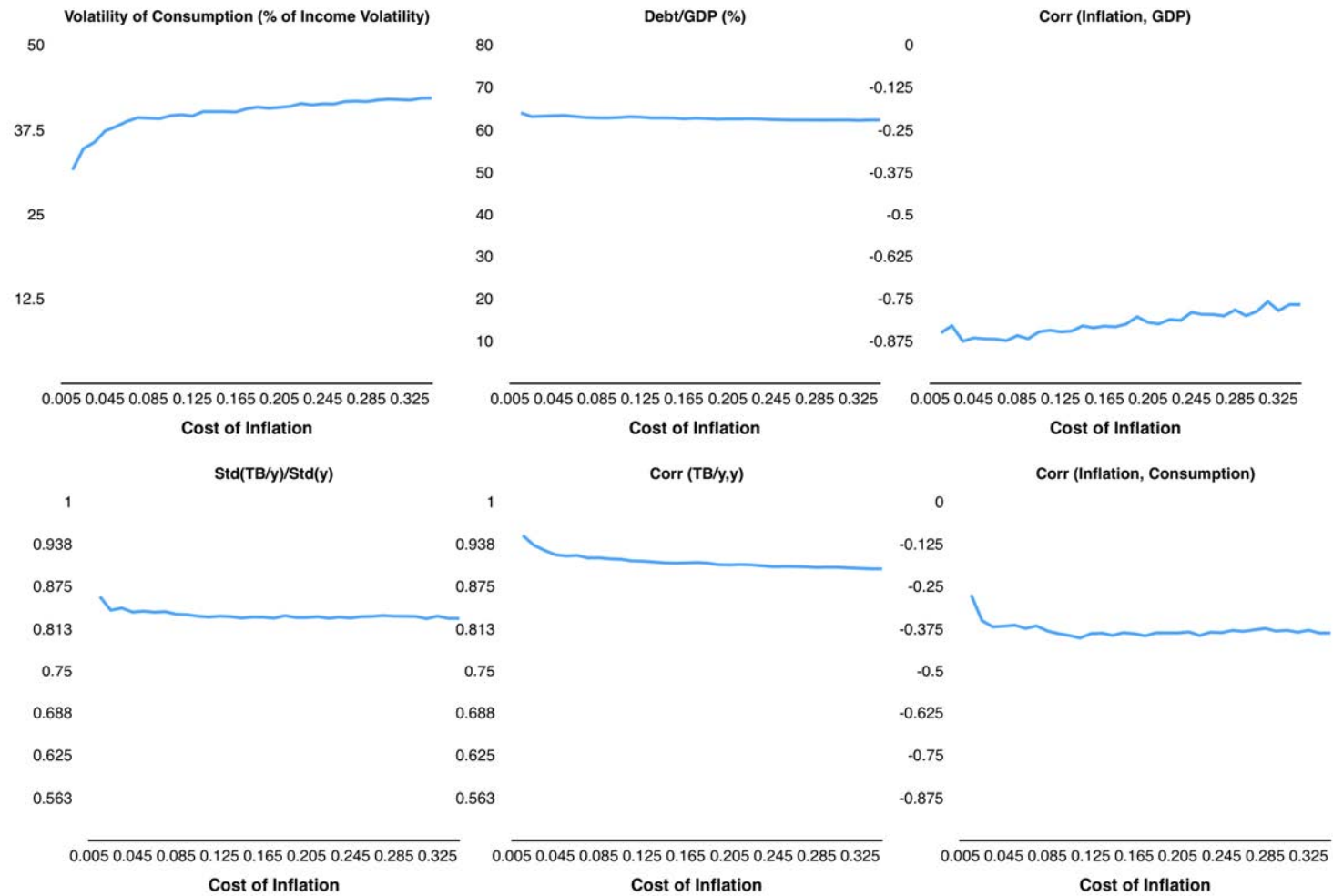


Figure 6 Addendum: Sensitivity Analysis w.r.t Discount Factor

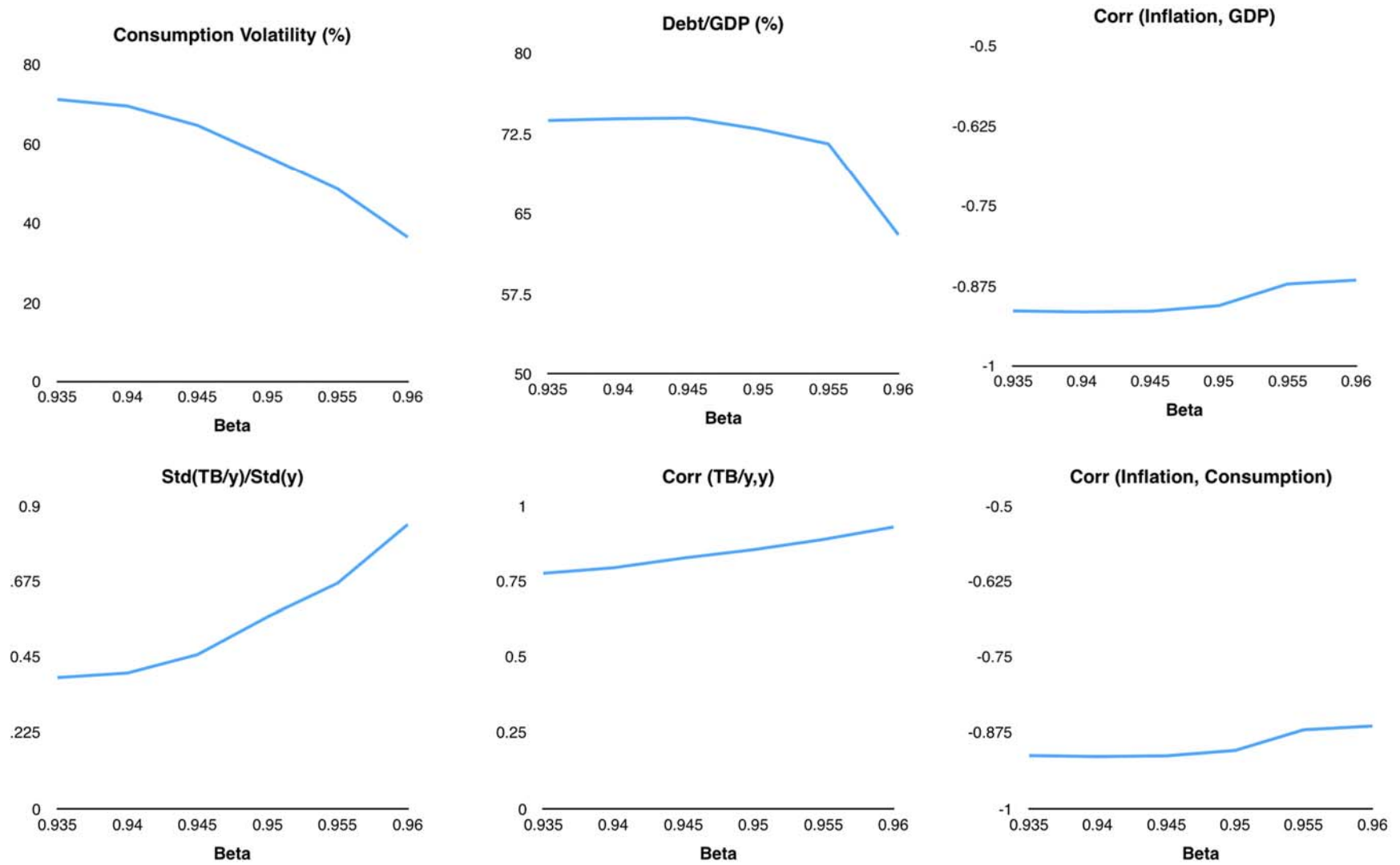


Figure 7 Addendum: Sensitivity Analysis w.r.t Risk-Averseness

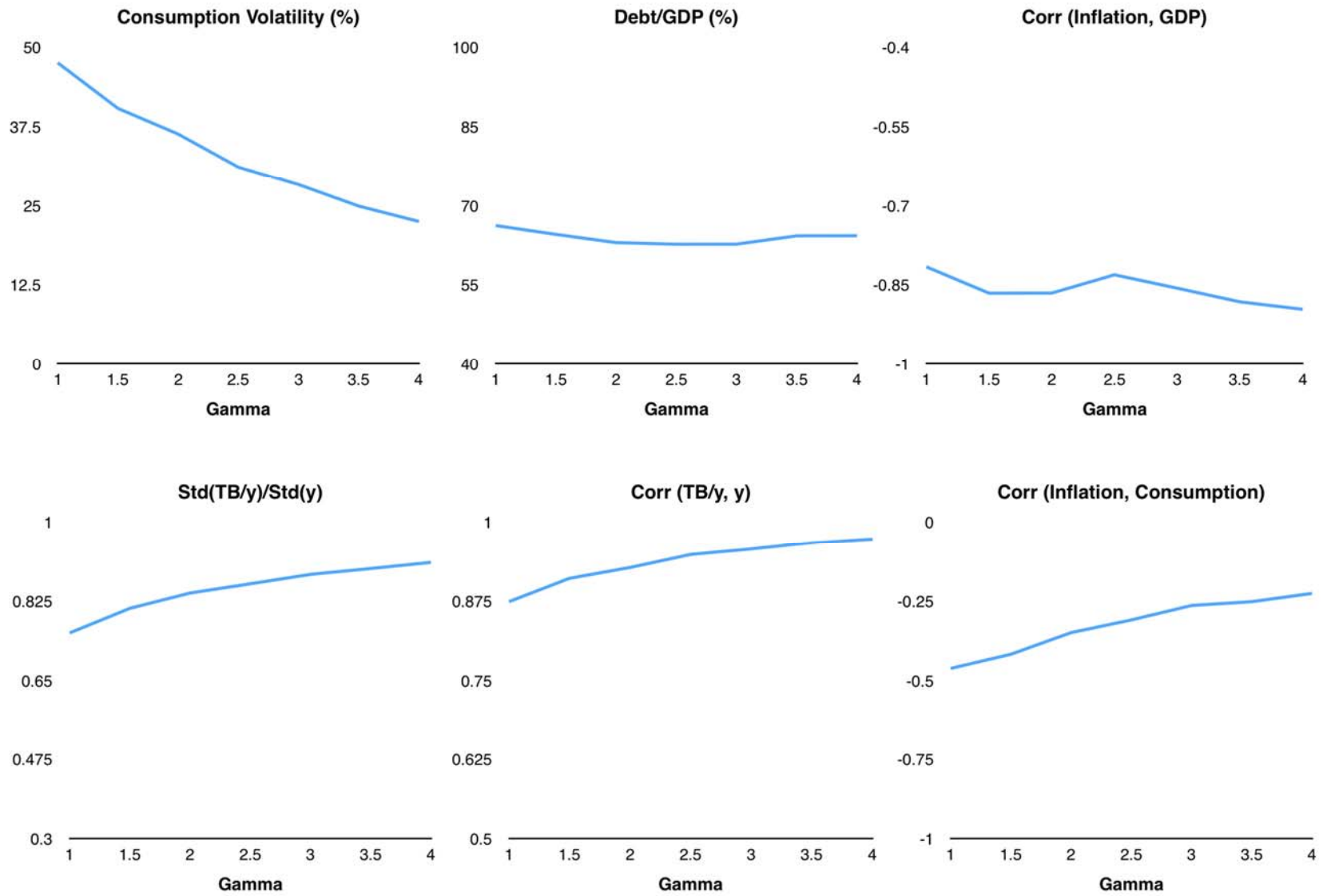


Figure 8 Addendum: Sensitivity Analysis w.r.t Output Cost of Default

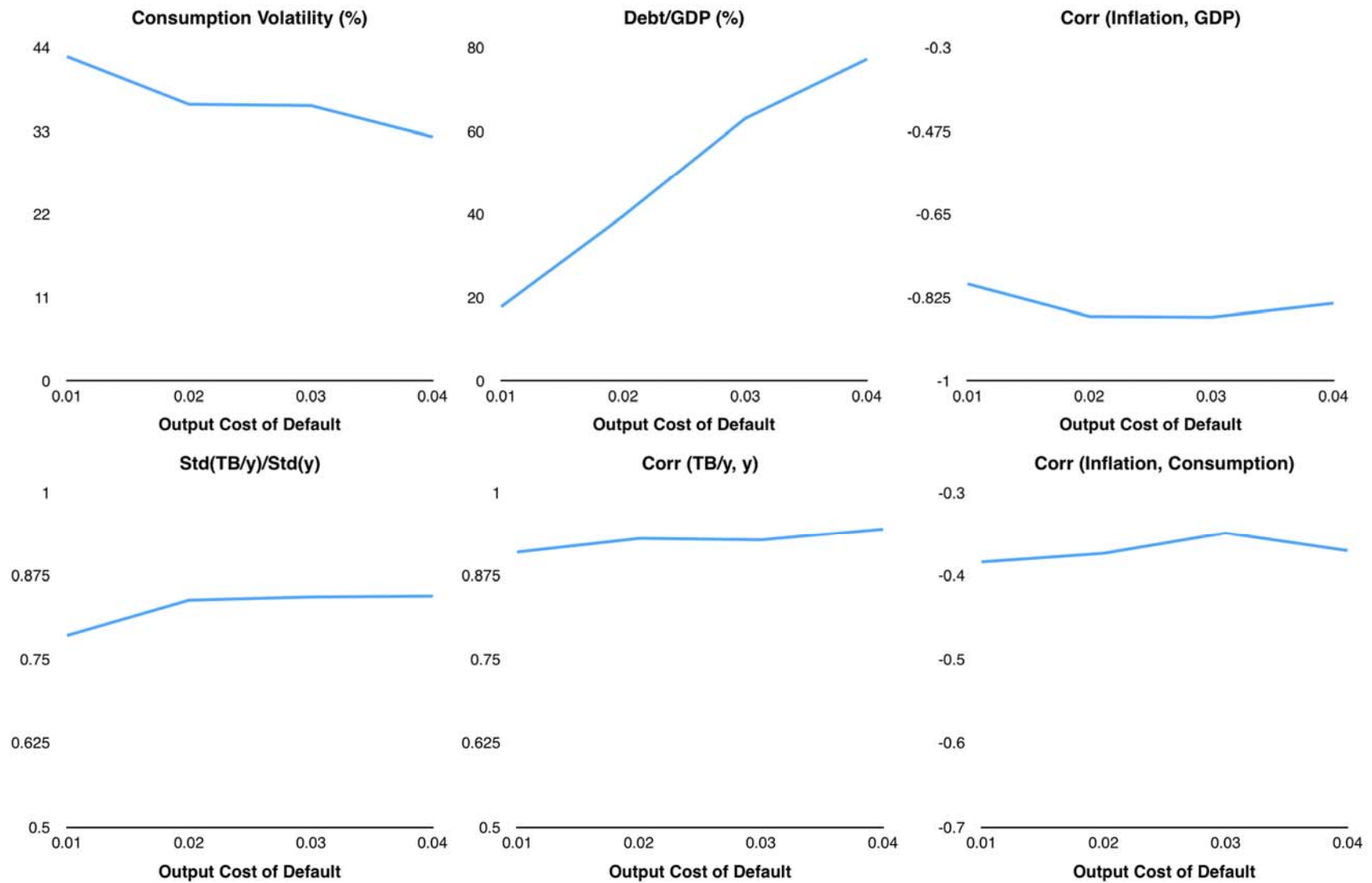


Figure 9 Addendum: Sensitivity Analysis w.r.t Persistence of Income Shock

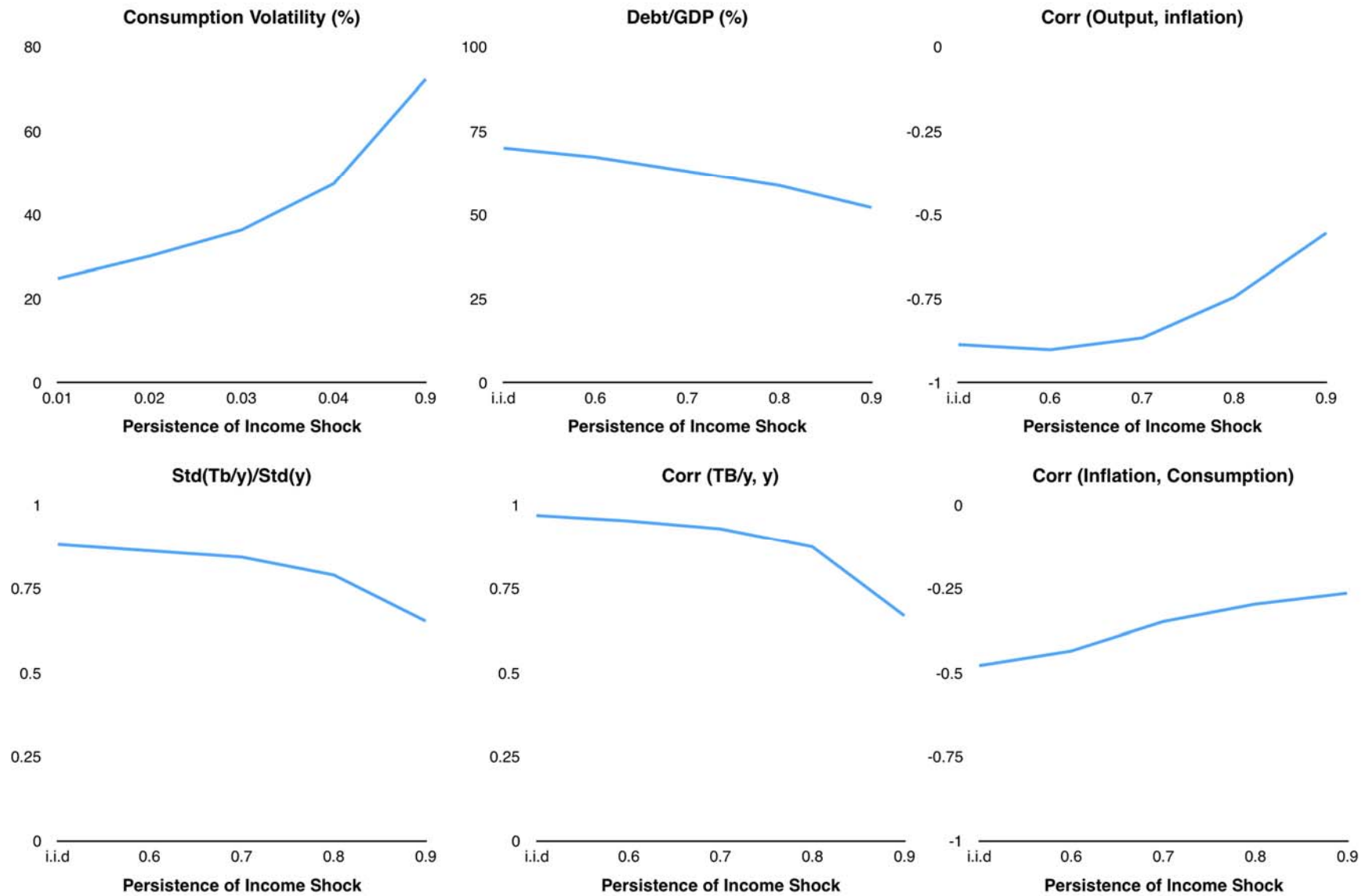


Figure 10 Addendum: Sensitivity Analysis w.r.t Variance of Income Shock

