Debauchery and Original Sin:

The Currency Composition of Sovereign Debt

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Abstract

We present a model that accounts for the "mystery of original sin", and the surge in local currency borrowing by emerging economies in the recent decade. We quantitatively investigate 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 act as a better consumption hedge against income shocks than foreign currency debt because their real value can be affected by monetary policy. However, this provides a government with more temptation to deviate from disciplined monetary policy, thus restricting borrowing in local currency more than in foreign currency. Our model predicts that a country with less credible monetary policy borrows mainly in foreign currency as a substitute for monetary credibility. 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 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 (Ems) to borrow abroad in their own currency has significantly improved in the last decade.[3]

A sovereign government faces a temptation to inflate away the real value of local currency debt obligations. This temptation to debase or "debauch" the currency may lead 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]

Building on this idea, a number of studies propose theoretical models that attribute the predominance of foreign currency external borrowing to EMs' monetary and fiscal indiscipline, and study its implications for EMs' economic policy and performance (e.g., Calvo (1978); Jeanne (2005); Cespedes, Chang, and Velasco (2004); Corsetti and Mackowiak (2005)). However, Eichengreen, Hausmann, and Panizza (2005), 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 the share of external debt denominated in local currency.

Eichengreen, Hausmann, and Panizza (2005) call this empirical finding the "mystery of original sin", as EMs seem to suffer from an inherited burden from the past, regardless of the government's policies, or their legal or political institutions. They claim that the original sin problem of EM economies is exogenous to a country's economic fundamentals– it is rather related to the structure of the international financial system.

[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.

In this paper, we build a full model of the dynamic contracting problem in a setting of debasement and default to account for EM economies' original sin problem and the "mystery of original sin". We make the point that contrary to Eichengreen, Haussmann, and Panizza (2005), the original sin problem can be mainly attributed to a country's monetary indiscipline, but that the relationship between endogenous variables, such as inflation performance, and the currency composition of debt is not straightforward.

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 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 excessive currency debasement may be too high for the borrowers with a low cost of inflation. When there is lack of commitment to a sovereign government's monetary policy, there is a tension between wishes of sovereign borrowers and lenders regarding how much to borrow and lend in local currency, thus leading to a possibly indirect relationship between inflation performance and the local currency share of sovereign debt.

Using the recent data set by Arslanalp and Tsuda (2014, 2020), we reconfirm the "mystery of original sin": The share of external sovereign debt denominated in domestic currency is not directly related to observable macroeconomic performance. But we do find evidence that the share of local currency (LC) debt is related to the decision to use inflation targeting as a monetary policy, to the political stability of the government, and to the depth of capital markets. These variables, in turn, have counterparts in structural parameters in our model.

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 fiscal discipline: 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.

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. 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 risk-free rate prevailing in the international financial markets. Since the real value of repayment for local currency debt can change depending on the ex-post inflation rate (currency depreciation rate), the foreign investors and the sovereign agree to a local currency debt contract that specifies an inflation rate at each state of the world.

To model inflation targeting – a time-consistent monetary (exchange rate) policy under commitment – we consider an optimal self-enforcing contract that maximizes utility of the representative household in the small open economy and that prevents the government from breaching the contract in any state of the world.[5] Our approach to modelling the local currency debt contract featuring a government's state contingent monetary policy is in line with the optimal dynamic contracting approach to sovereign borrowing (e.g., Atkeson (1991); Kehoe and Levine (1993); Alvarez and Jermann (2000); Aguiar, Amador, and Gopinath (2009)). This framework is more suitable for studying a committed time-consistent monetary policy than the Markov equilibrium approach which quantitative incomplete market sovereign default models adopt (e.g., Aguiar and Gopinath (2006); Arellano (2008); Ottonello and Perez (2019)). The latter is better suited for studying discretionary monetary policy.

Why do we connect the ability to borrow in local currency with the adoption of an inflation-targeting monetary policy? Inflation targeting is a form of monetary policy commitment, whose analog in our framework is the willingness of the sovereign borrower to adopt a local-currency contract with state contingent inflation rates. Svensson (1997) points out that a strong commitment to a systemic monetary policy through inflation targeting can mimic the optimal inflation contract offered to an independent central banker suggested by Walsh (1995). This optimal contract can also be thought of as a credible time-consistent optimal monetary policy in a similar vein to Lucas and Stokey (1983) and Chang (1998). Moreover, the structure of the local currency debt contract in the model mimics the inflation targeting framework in the real world: it features a target inflation rate with flexible inflation rate bands.

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. 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 consumption hedging benefit of local currency debt. Meanwhile, the enforcement constraint arising from the option to fully default on its debt mainly determines the endogenous borrowing limit for foreign currency debt. These two enforcement frictions combine to generate an endogenous debt frontier, determining the maximum amount of debt in each currency.

In our model, as well as in reality, a sovereign's default on debt is generally more costly for its economy than excessive currency debasement. Costly default provides foreign currency debt with more credibility than local currency debt, thus allowing the sovereign to borrow more in foreign currency. This extra credibility from costly default makes foreign currency debt valuable, whereas the state-contingency inherent in local currency debt makes local currency debt valuable: a sovereign with less disciplined

[5] We use the term "inflation targeting" throughout, though in fact, the model incorporates monetary policy that is akin to price-level targeting. That is, high inflation in some states of the world is balanced by low inflation in other states in the optimal contract.

monetary policy borrows mainly in foreign currency as a substitute for monetary credibility. Thus, we see a mix of foreign and local currency debt in equilibrium.

We calibrate the model to a panel of nine EM economies which adopted inflation targeting in the last decade. The quantitative results show that a 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. More disciplined countries can borrow more in local currency, which provides a better consumption hedge. A 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 constraint. We also conduct a dynamic analysis to account for the recent increase in EM economies' local currency borrowing. We find that the increase in a country's monetary credibility, represented by a cost of inflation in our model, almost exclusively accounts for the recent increase in EM's local currency borrowing.

The currency composition of debt and variables such as the volatility of inflation are all endogenous. They depend on the economy's characteristics such as the degree of patience and risk aversion, and the cost of default and inflation as well as its income shock process. The cross-country analysis, in which we calibrate the model to each of 9 countries, shows that there is no simple monotonic relationship among these variables, which may account for the lack of a 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 if it is in financial autarky, monetary policy is discretionary. But when a country can obtain a contract to borrow in local currency, the value of that contract is a commitment device that allows the policymaker to stick to a state-contingent pre-announced monetary policy.

In section 2, we revisit the mystery of original sin problem by Eichengreen, Hausmann, and Panizza (2005), and Hausmann and Panizza (2003) to empirically investigate the determinants of the original sin problem. In section 3, we present our formal model. In section 4, we calibrate the model to a panel of 9 EM economies and conduct both dynamic and cross-country analysis to investigate what drives observed variation in LC borrowing in the cross-section and across time. Then section 5 presents the model with a Phillips curve.

Related Literature

Our work builds on the intuition from the classical argument that attributes the predominance of foreign currency debt in international financial markets to a lack of monetary credibility. A government's strategic debasement of 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 an exogenous cost to inflation. In more recent work, Ottonello and Perez (2019) 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. Ottonello and Perez (2019), however, study discretionary policy rather than committed time-consistent policy with the same frictions. 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.[6]

Phan (2017) examines an Eaton-Gersovitz (1981) 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 debt can be sustained even if the punishment for default or complete debasement of local-currency debt allows for the country to save in the foreign currency assets. It thus offers a possible resolution to the Bulow and Rogoff (1989) puzzle concerning the sustainability of sovereign debt when exclusion is the only punishment for default, but, in common with Bohn and Ottonello-Perez, it cannot account for original sin.

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 negotiate a contract 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).

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 borrowing limits arising from the limited enforcement problems can cause significant distortions to allocations of an economy. As in these studies, there are no equilibrium breaches of the contract in our model.

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

[6] See also Du et al. (2020), who consider a two-period framework with risk averse lenders and compare the cases of a borrowing sovereign without and with commitment.

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.

2. Empirical Analysis

2.1 Mystery of Original Sin Revisited

Eichengreen, Hausmann, and Panizza (2005), and Hausmann and Panizza (2003) find that 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 measures of economic development. 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 EM economies is exogenous to a country's economic fundamentals.

Ogrokhina and Rodriguez (2018) reexamine the economic determinants of local-currency debt. They confirm the findings that typical measures of inflation performance have limited power in accounting for which countries are able to issue local-currency government debt. However, they introduce some new variables which do partially unlock the mystery, and which are consonant with the model we present. In particular, they find evidence that countries that adopt inflation targeting have been more successful at issuing sovereign debt denominated in local currency – and that effect is independent of actual inflation performance.

These studies have relied on a less-than-perfect measure of foreign-held local-currency sovereign debt, relying primarily on measures of local-currency debt issued in foreign markets. Two new studies have tried to carefully measure all sovereign debt held outside a country's borders, including by currency denomination of the debt, irrespective of whether the debt was issued abroad or within the sovereign. The studies, by Du and Schreger (2016b) and Arslanalp and Tsuda (2014, 2020) have a narrower range of country coverage than the previous studies, but the data they produce more neatly lines up with the variable of interest in our study, which is the amount of sovereign debt held abroad that is denominated in local currency. The measures in the two studies are highly correlated. We use Arslanalp and Tsuda's data, which is publicly available and periodically updated.

The country coverage of the data set is spotty prior to 2010, so we cannot undertake an extended time series analysis. Eliminating from the study countries such as China and India, for which only a small fraction of their sovereign debt is held by foreigners, whether in local currency or not, leaves nineteen countries to investigate. Figure 1 displays the evolution of the share of their debt held externally that is denominated in local currency.

Many of the countries in the sample were undergoing a shift in the early years of the 2000s, from a regime in which little or none of their sovereign debt was local currency, toward a regime in which a significantly larger fraction was. By the end of the sample, for example, around 90 percent of Malaysia's and Thailand's debt was in local currency. Other countries, such as Brazil, Mexico and South Africa saw significant increases. On the other hand, some countries saw very little increase in the share of debt in local currency.

One likely explanation for the increase is that most of the countries in the sample officially adopted inflation targeting as their monetary policy stance in the late 1990s or early 2000s. There were twelve countries in the sample in this category: Brazil (adopted in 1999), Colombia (1999), Hungary (2004), Indonesia (2005), Mexico (2001), Peru (2002), Philippines (2002), Poland (1998), Russia (2008), South Africa (2000), Turkey (2006) , and Thailand (2000). In addition, Malaysia was understood to be an inflation targeter, but they did not adopt that position officially. Only six of the countries did not adopt inflation targeting: Argentina, Bulgaria, Latvia, Lithuania, Romania, and Ukraine. In all these cases, the share of external debt denominated in local currency remained very low throughout the time period.

However, a complication to our empirical analysis is that several countries in the sample were committed to joining the euro area. In fact, Latvia (in January 2014) and Lithuania (in January 2015) did adopt the euro. The data includes euro-denominated debt as foreign-currency debt, but that is an ambiguous proposition for these countries. Romania, Bulgaria, Hungary and Poland also are in this group, though none has yet adopted the euro. However, as noted, Hungary and Poland continued to devote their monetary policy toward inflation targeting. In our regression analysis, then, we will classify those two countries as pursuing inflation targeting; and, we will group the countries that do not target inflation separately into those looking to join the euro area, and the two remaining countries, Argentina and Ukraine. Although the fraction of local-currency sovereign debt held abroad is low for all the countries that do not target inflation, the reason might be different for the European countries versus the other two.

Figure 2 presents scatterplots of the share of externally held debt in local currency against measures of inflation performance. The share of home currency debt is measured as the average over the 2010-2019 period. The first panel of the figure illustrates the relationship between average inflation rates (for the 2000-2019 period) and local-currency share, while the second panel graphs the standard deviation of annual inflation (again for 2000-2019) against local currency shares. Figure 2 illustrates the mystery of original sin – there appears to be very little relationship between inflation performance and the share of debt held abroad that is denominated in local currency. We look at the share of debt over the 2010-2019 period because the currency composition of debt takes some time to adjust even after a country has adopted inflation targeting. There might be a lag between the implementation of the policy and when markets conclude that the policy commitment is credible, but also some foreign-currency debt is longer term so it takes time for its share in total externally held debt to decline.

Table 1 presents panel estimates of the determinants of the share of externally held foreign debt denominated in local currency for the nineteen countries, using annual data, 2010-2019. Inevitably, because of the paucity of data, it is not judicious to include a large number of explanatory variables in a single regression. The reported regressions consider nine independent variables, in various combinations: A dummy variable for the countries that did not adopt inflation targeting; a dummy variable for the countries that were aiming to adopt the euro; annual inflation; the Chinn-Ito measure of capital account openness; the World Bank's World Development Indicator measure of financial development, domestic credit relative to the non-government component of GDP; log of total GDP, and log of GDP per capita; and the indexes of government effectiveness and political stability from the World Bank's World Governance Indicator.

The countries that did not adopt inflation targeting had significantly lower shares of local-currency debt. The apparent upswing in local-currency sovereign debt appears to be related to the adoption of inflation-targeting monetary policy, as Ogrokhina and Rodriguez (2018) found in their dataset of foreign-issued debt. Additionally, Bulgaria and Romania issued little domestic currency debt, and instead sold debt to foreigners denominated in euros, consistent with their aim to join the euro area.

Inflation performance itself has little explanatory power, which is consistent with the mystery of original sin documented by Eichengreen, et al. (2005), and Hausmann and Panizza (2003). We have also included measures for the size of the country (log GDP) and the level of income per person (log of GDP per capita.) The former measure had explanatory power in the earlier studies, but we generally find that it does not, except in the first specification of Table 1. As in the earlier studies, income per person as a proxy for economic development is not helpful in explaining currency denomination of sovereign debt.

We do find a few measures that have success in explaining the ability to sell sovereign debt abroad that is denominated in local currency. We find that countries with greater financial development, and countries with greater government effectiveness are better able to issue domestic-currency debt.

Overall, our findings are similar to the earlier studies of original sin. We have, in Table 1, reported results for some of the variables that were successful in accounting for local-currency debt, but we looked at many more. In panel regressions, we considered measures such as the total government debt relative to GDP, trade openness and other measures of governance. We also did cross-sectional regressions and considered more measures of inflation performance such as average inflation, the standard deviation of inflation, and the maximum inflation rate over various sub-periods. We also considered as explanatory variables the classification of the exchange-rate regime from Ilzetzki et al. (2019) and the Fernandez et al. (2016) measure of capital control intensity. None were useful explanatory variables.

We note that variables that do appear to predict that a country can escape original sin and issue significant amounts of local-currency debt – commitment to inflation targeting, financial development, and government effectiveness – have analogs in the form of deep parameters in our theoretical model. In section 4, we calibrate the model and examine whether the calibrated parameters are consistent with their empirical counterparts.

Figure 1: Share of Debt in Local Currency

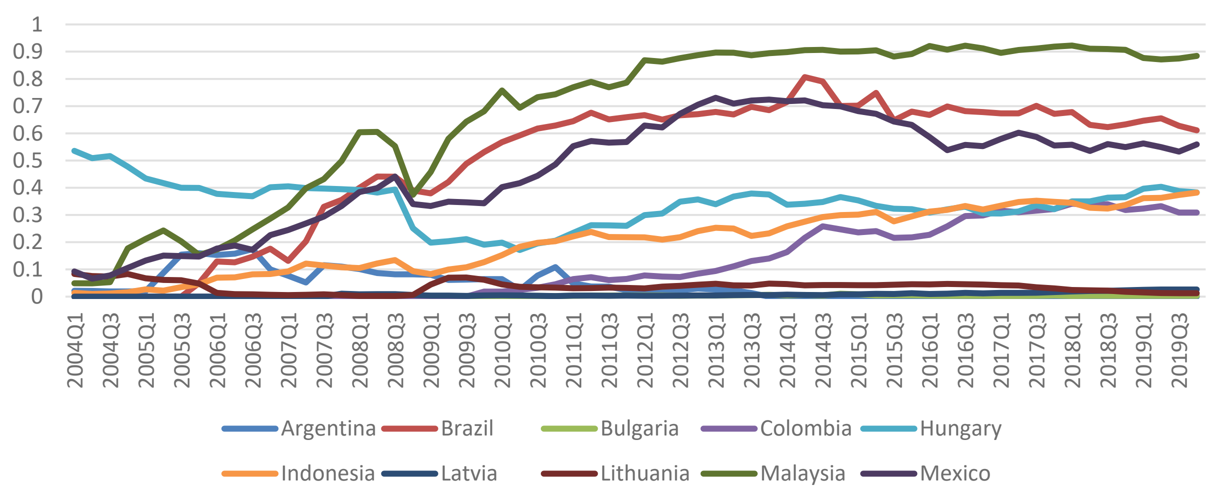


Figure 1 (cont.): Share of Debt in Local Currency

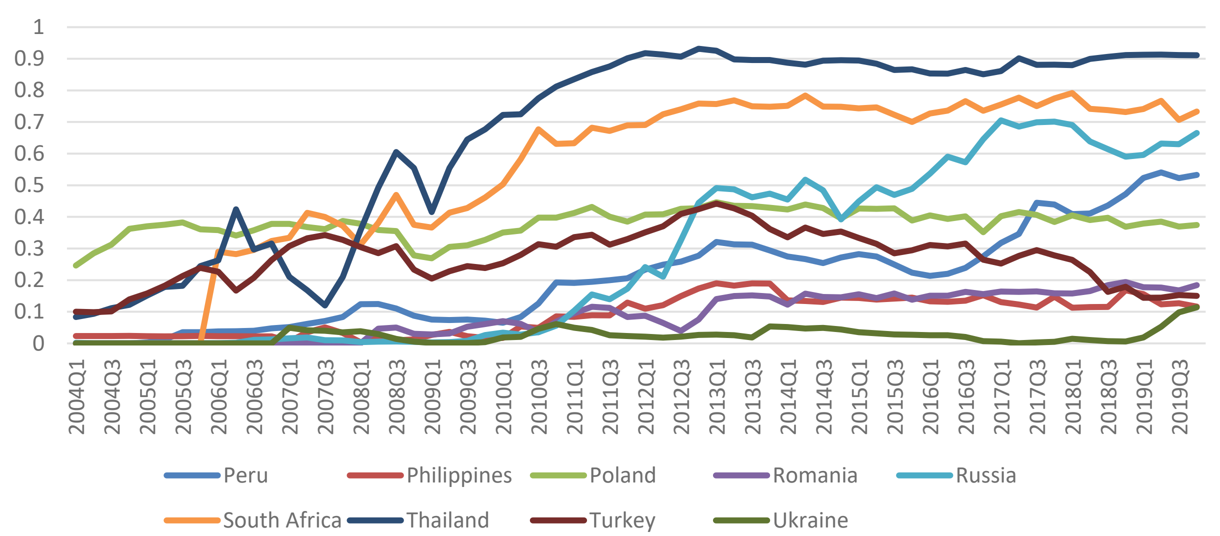
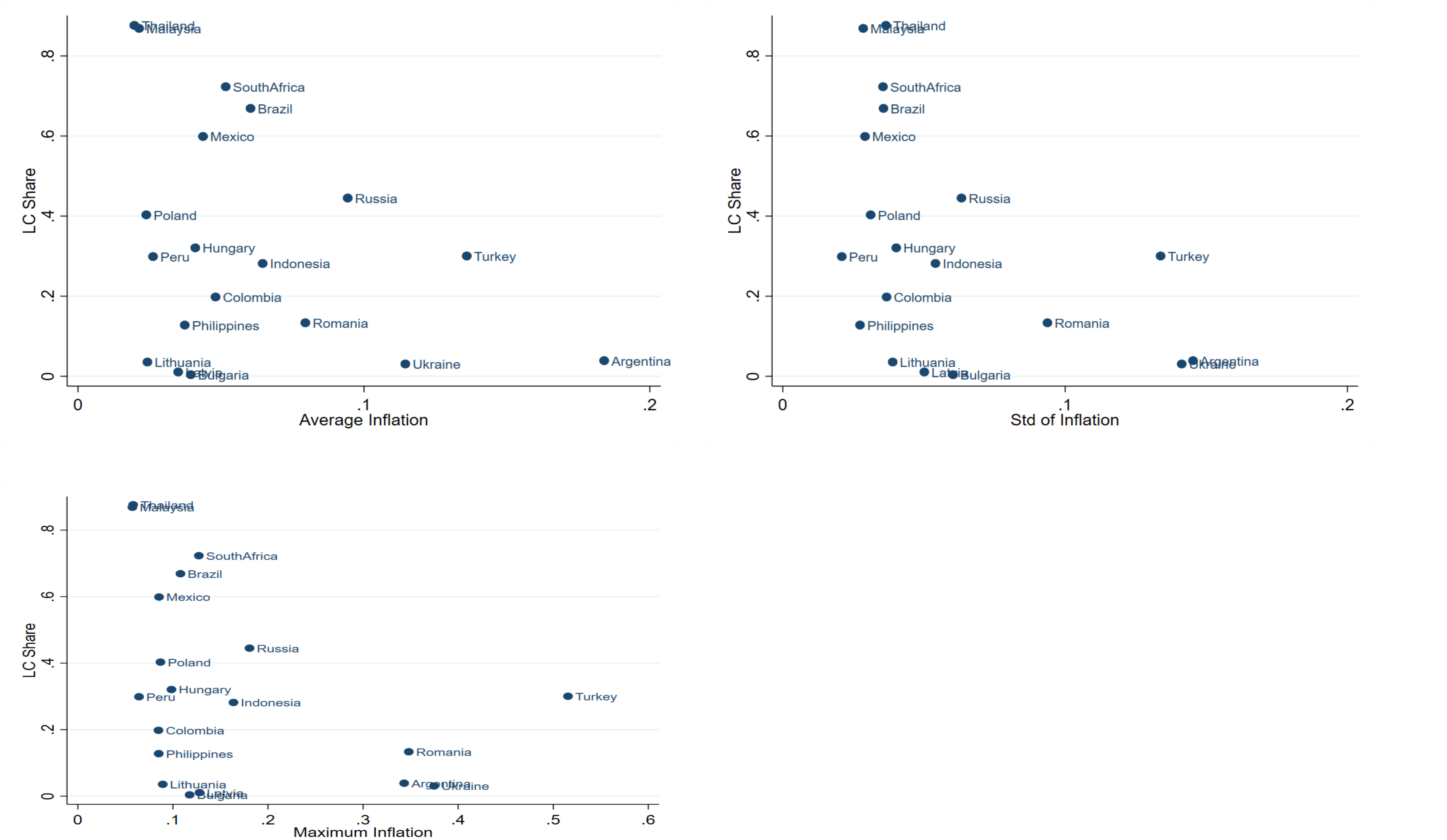


Figure 2: LC Share and Inflation Volatility



Note: Local currency share refers to the share of externally held sovereign debt denominated in local currency. For LC share, we use the period average from 2010-2019. For the inflation related variables, we use the sample period from 2000 to 2019.

Table 1 – Determinants of Local-Currency Foreign-Held Sovereign Debt

Dependent variable: Share of Externally Held Sovereign Debt Denominated in Local Currency
Panel Ordinary Least Squares, Annual, 2010-2019

	(1)	(2)_	(3)	(4)	(5)	(6)	(7)	(8)
Inflation non-targeter	-0.1103	-0.4048***	-0.4202***	-0.3630***	-0.3745***	-0.4183***	-0.3070**	-0.4271***
	(0.1137)	(0.0802)	(0.0769)	(0.0757)	(0.0877)	(0.0769)	(0.0876)	(0.0744)
Joining euro area	-0.0968	-0.4291***	-0.4349***	-0.3786***	-0.2381*	-0.4491***	-0.4829***	-0.4887***
	(0.1142)	(0.0740)	(0.0810)	(0.0674)	(0.1349)	(0.0753)	(0.1020)	(0.0786)
Inflation	0.0006	-0.0022						
	(0.0014)	(0.0021)						
Capital acct. openness	0.0288		0.0315					
	(0.0753)		(0.0659)					
Dom. Credit/GDP	0.3062***			0.2473**				
	(0.0852)			(0.1161)				
ln(GDP)	0.1564***				0.0874			
	(0.0532)				(0.0534)			
ln(GDP) per capita	-0.1255					0.0660		
	(0.1140)					(0.0677)		
Govt. effectiveness	0.2612**						0.2221**	
	(0.1072)						(0.1017)	
Political stability	0.0333							0.0732
	(0.0319)							(0.0457)
N	166	184	166	184	184	184	184	184

Table 1 (continued) – Determinants of Local-Currency Foreign-Held Sovereign Debt

Dependent variable: Share of Externally Held Sovereign Debt Denominated in Local Currency
Panel Ordinary Least Squares, Annual, 2010-2019

	(9)	(10)_	(11)	(12)	(13)	(14)	(15)	(16)
Inflation non-targeter	-0.2995***	-0.4198***	-0.1951**	-0.3957***	-0.2406**	-0.3921***	-0.2877***	-0.4203***
	(0.1041)	(0.0787)	(0.0929)	(0.0701)	(0.1038)	(0.0895)	(0.0923)	(0.0763)
Joining euro area	-0.4788***	-0.4875***	-0.4404***	-0.4348***	-0.3036**	-0.3721**	-0.4881***	-0.4906***
	(0.1012)	(0.0839)	(0.1080)	(0.0638)	(0.1515)	(0.1697)	(0.0945)	(0.0752)
Inflation	-0.0011	0.0003	-0.0011	-0.0007	-0.0006	-0.0000	-0.0014	-0.0003
	(0.0008)	(0.0015)	(0.0014)	(0.0019)	(0.0013)	(0.0020)	(0.0014)	(0.0020)
Capital acct. openness	0.0146	0.0279						
	(0.0695)	(0.0658)						
Dom. Credit/GDP			0.2780***	0.2042**				
			(0.1046)	(0.1032)				
ln(GDP)					0.0845*	0.0511		
					(0.0480)	(0.0411)		
ln(GDP) per capita							0.0089	0.0107
							(0.0783)	(0.0846)
Govt. effectiveness	0.1897*		0.2459***		0.2199**		0.2171*	
	(0.1042)		(0.0918)		(0.1015)		(0.1133)	
Political stability		0.0629		0.0530		0.0643		0.0700
		(0.0396)		(0.0402)		(0.0474)		(0.0517)
N	166	166	184	184	184	184	184	184

The table reports the OLS estimates of the coefficient of the panel regression listed. The data are annual, 2010-2019. There is an intercept term in each regression, not reported. The 19 countries in the sample include the inflation-targeting countries of Brazil, Columbia, Hungary, Indonesia, Malaysia, Mexico, Peru, Philippines, Poland, Russia, South Africa, Turkey, and Thailand. The countries dummied as aiming to join the euro area are Bulgaria and Romania. The two dummied as non-inflation targeters are Argentina and Ukraine. Inflation is CPI inflation. Capital account openness is the Chinn-Ito measure. Domestic credit to the private component of GDP is from World Development Indicators of the World Bank., The measures of government effectiveness and political stability are from the World Bank's World Governance Indicators.

OLS standard errors in parentheses. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

3. The Model Economy

We consider a standard small open economy model, extended to allow a sovereign government to borrow in both local and foreign currency from foreign lenders in international financial markets. Time is discrete ($t = 0,1,2,3\ldots$) and runs forever. Before the income shock is realized at period 0, the sovereign attempts to arrange a local currency debt contract with the foreign lenders. If the sovereign and foreign lenders successfully agree on terms of a local currency debt contract, the small open economy can borrow in both currencies thereafter. On the other hand, if the sovereign and foreign lenders fail to agree, the economy may borrow only in foreign currency thereafter.

The representative household receives stochastic endowment shocks every period and has preferences given by

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

where β denotes the time discount factor, c_t consumption, π_t the gross inflation rate at period t (i.e., P_t / P_{t-1}), and $\bar{\pi}$ the target inflation rate of the country. The period utility function $u(.)$ is differentiable, strictly increasing, strictly concave and satisfies the standard Inada conditions. Following Barro and Gordon (1983), we introduce a cost of inflation in the form of utility loss $C(\pi_t - \bar{\pi})$, which is differentiable and is 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 to maximize welfare of this economy.

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

$$P_t c_t + S_t P_t^* b_{t+1}^{for} + P_t b_{t+1}^{loc} = P_t y_t + R^* S_t P_{t-1}^* b_t^{for} + i_t P_{t-1} b_t^{loc}, \quad (2)$$

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^* the constant gross risk-free rate prevailing in international financial markets.[7] We assume that b_0^{for} and b_0^{loc} are initially given , $P_{-1}=1$, and y_{-1} is given with $\Pr(y_{-1})=1$. We also assume that the law of one price holds and the foreign price P_t^* is normalized to be 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

$$c_t + b_{t+1}^{for} + b_{t+1}^{loc} = y_t + R^* b_t^{for} + \frac{i_t b_t^{loc}}{\pi_t}. \tag{3}$$

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. Finally, we impose the natural debt limit following Aiyagari (1994) given by

$$\left(b_{t+1}^{for} + b_{t+1}^{loc}\right) \geq -D, \tag{4}$$

where $D = \underline{y} / \left(R^* - 1\right)$ 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 simultaneously. Selective default on a certain type of debt is not allowed in our model, consistent with practices in sovereign debt markets and the theory in the sovereign debt literature.[8] Second, the government can debase its currency more than required in the local currency contract, 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 fiscal indiscipline: strategic default and debasement.

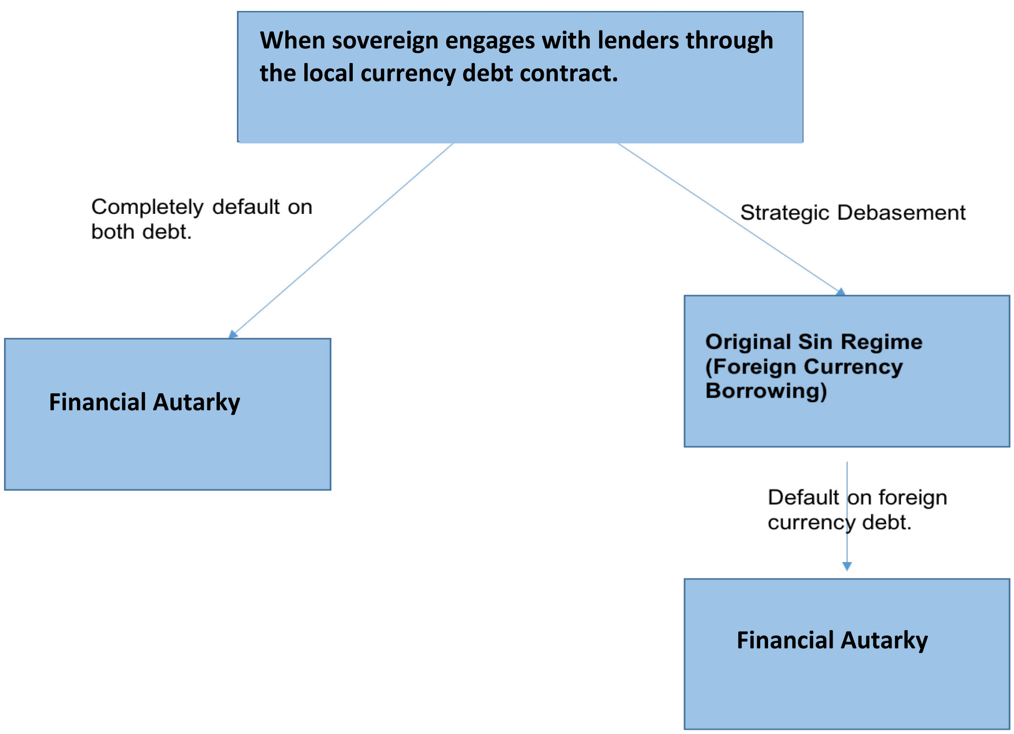
When the government fully defaults on its debts, the economy enters financial autarky, during which it loses access to international financial markets. When the government breaches the contract through excessive currency debasement, the country is restricted to borrow only in foreign currency as a punishment, thus entering the original sin regime. When the government in this regime defaults on its foreign currency debt, the economy also enters financial autarky. Figure 3 summarizes the two different types of breaches of the debt contract and their consequences.

[7] Since we investigate the currency composition of two types of sovereign debts, we don't allow the government to accumulate assets. $b^{loc} > 0$ is ruled out, because 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. We don't allow $b^{for} > 0$, because we want to rule out an equilibrium in which the economy borrows *only* in local currency and save *only* in foreign currency at the same time. In any case, the no accumulation constraint is not binding in the simulations. This is because when $\beta(1+r^*) < 1$, the economy wants to borrow to achieve a front-loaded consumption profile, but due to debasement risk, the economy cannot borrow in local currency as much as it wants. In this case, the economy needs to rely on foreign currency debt to satisfy its borrowing need.

[8] See Broner et. al. (2010) for a theoretical study on this problem.

In the benchmark model, we assume temporary financial autarky as a punishment for outright default and permanent original sin regime as a punishment for excessive debasement. However, even if we assume temporary original sin regime as a punishment for the excessive debasement, our main results carry through. (See Appendix D)

Figure 3: 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 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^*. Even if local currency debt is non-contingent in nominal terms with a gross nominal interest rate i_t, depending on the government's ex-post choice of the inflation rate π_t (or equivalently currency depreciation rate), the real rate of interest on local currency debt i_t / π_t can differ. We consider the following recursive contract for local currency debt, which consists of two components: a nominal gross interest rate i_t and state contingent inflation rates in the next period π_t.[9]

$$i_t = I\left(b_t^{for}, b_t^{loc}, y_{t-1}\right) \tag{5}$$

$$\pi_t = \Pi\left(b_t^{for}, b_t^{loc}, y_{t-1}, y_t\right) \tag{6}$$

When the sovereign government borrows b_t^{for} and b_t^{loc} in foreign and local currency in period $t-1$, the contract specifies a nominal gross interest rate i_t on local currency debt b_t^{loc}. Moreover, the contract asks for an inflation (currency depreciation) rate that depends on the realization of y_t in period t.

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:

$$R^* = \sum_{y_t} Pr\left(y_t \mid y_{t-1}\right) \frac{i_t\left(b_t^{for}, b_t^{loc}, y_{t-1}\right)}{\pi_t\left(b_t^{for}, b_t^{loc}, y_{t-1}, y_t\right)} \tag{7}$$

Note that $\Pi(\ )$ contains y_{t-1} as well as y_t because of the persistent income shock process $\Pr\left(y_t \mid y_{t-1}\right)$ in eq (7). In the next section, we specify an optimal self-enforcing local currency contract subject to the lenders' zero-profit condition, to model inflation targeting as a state-contingent monetary policy under commitment. Due to the zero profit condition (eq (7)), a currency depreciation (or equivalently π_t above the target inflation rate $\bar{\pi}$) at a certain state in the contract must be accompanied with a currency appreciation (i.e., π_t below $\bar{\pi}$) at other states.

This local currency contract featuring the government's state-contingent monetary policy mimics the inflation targeting framework in the real world: inflation targeting usually takes a form of a target inflation rate $\bar{\pi}$ with flexible inflation rate bands. In this context, the breach of the local currency contract through excessive debasement can be interpreted as a sovereign's breach of the self-announced inflation rate bands by conducting a reckless monetary policy, which leads to high or hyperinflation in the economy[10]; once the

[9] It is restrictive to consider only recursive contracts even though this particular form of the recursive contract imposes no additional restrictions. When the contract is not Markov (i.e., the contract is history dependent.), it could take many different forms. For example, investors could propose a contract which asks for additional interest premiums on the bonds issued by the sovereigns which have a history of breaching the contract.

[10] Unlike default, which is a discrete event, excessive debasement- deviation from the inflation target - is continuous, so upon even an infinitesimal deviation from the inflation target, the punishment must kick in. However, in practice, when the sovereign decides to breach the contract through excessive debasement, it would choose a finite level of inflation substantially above the inflation target, to equate the benefit of inflating away of local currency debt and the cost of inflation at the margin. If inflation costs are zero, the country will generate an infinite inflation. Upon observing this high inflation, lenders would stop lending in local currency to the sovereign, which has lost monetary reputation.

sovereign decides to deviate from the contracted inflation rate, it will choose a very high inflation rate to maximize a reduction in the real value of the local currency debt.

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 non-contingent debt. From now on, x_t denotes the vector of state variables at period *t*, which consists of $\left(b_t^{for}, b_t^{loc}, y_{t-1}, y_t\right)$.

Discussion of Main Assumptions

Two Types of Punishment

Our paper derives a reputational equilibrium as in Eaton and Gersovitz (1981), but a sovereign government in our model has two types of reputation: repayment and monetary reputation. If a sovereign defaults on its debt, whether it is in foreign or local currency, it loses repayment reputation, banning it from international financial markets. As with the sovereign debt literature and empirical evidence, we assume that a defaulting country enters financial autarky temporarily, regaining access to international financial markets after a stochastic number of periods. On the other hand, if the sovereign breaches the contract through excessive currency debasement, its monetary reputation is lost so lenders would not lend any amount in local currency (i.e., the country enters the original sin regime.). Note that lenders would lend in foreign currency to the sovereign that lost its monetary reputation but not the repayment reputation. This implies that the local currency lenders cannot impose financial autarky on the government that loses only its monetary reputation after excessive debasement: The foreign currency lenders will not cooperate with the local currency lenders in a punishment of financial autarky.[11]

Reinhart and Rogoff (2009) document the prevalence of high inflation periods for many countries throughout history, and that in the aftermath of high inflation or hyperinflation, these countries generally experienced a huge shift toward the use of foreign currency for transactions and borrowing (i.e., "dollarization"), because the governments' monetary credibility had been lost. Original sin is a specific case of dollarization (Yilmaz (2006)). The punishment of original sin for excessive debasement is motivated

[11] It is common for courts in unsecured lending countries to hinder the defaulting a sovereign's new issuance of debt by impairing the rights of new lenders until the sovereign reaches a settlement with the original lenders. But in the case of inflation, the nominal debt is repaid, so there is generally no legal grounds for prohibiting further lending to a high inflation country.

by this historical fact, as the punishment of financial autarky for outright default is motivated by the historical facts regarding sovereign defaults (Eaton and Gersovitz (1981)).

Unlike *temporary* financial autarky as a punishment for outright default, we assume a *permanent* original sin regime for the country which has breached the contract through excessive debasement, because there is no historical episode in which any countries suffered from a *temporary* original sin regime. Since the international financial liberalization in the late 1970s, only a handful of countries have been able to borrow externally in local currency (the U.S., U.K., Japan, Switzerland, and Germany), and the vast majority of countries were not able to borrow in their domestic currencies until recently.[12] EM economies' recent escape from the original sin should be thus viewed not as their *regaining* access to the ability to borrow in local currency, but as their having *overcome* the original sin problem after adopting the inflation targeting. Proposition 2 in section 2 shows that only countries with certain characteristics are able to borrow in local currency.

The punishment for excessive debasement – forcing the sovereign into the original sin regime – is generally less costly to the economy than the punishment of financial autarky for outright default. Corollary 2 in section 2 shows that if both outright default and excessive debasement are *equally* punished with financial autarky, local currency debt has no debasement risk, so the sovereign can always borrow in local currency. That is, we would not see any economy suffering from original sin in equilibrium with equal punishment, an implication that is not consistent with the fact that most EM economies still borrow only in foreign currency. The corollary provides additional support for our choice of different punishments for outright default and excessive debasement.

LC Debt Contract with State Contingent Inflation Rates

Unlike Atkeson (1991), Kehoe and Levin (1993), and Alvarez and Jermann (2000), which assume a full set of state-contingent claims traded internationally, we make a more realistic assumption that the asset markets are incomplete: the set of assets that the government can issue is restricted to non-contingent bonds in nominal terms, whether denominated in local or foreign currency.

Grossman and van Huyck (1988, 1993) point out that throughout history, international loans, while non-contingent in nominal terms, are state-contingent through frequent rescheduling of repayments, often via currency debasement. Grossman (1990), and Grossman and van Huyck (1993) suggest that the U.K. and the U.S.'s currency appreciation on returning to gold at the prewar parity after the Napoleonic War

[12] Bordo, Meissner, and Redish (2005) show historical cases in which how several countries including the U.S. have overcome the original sin problem in the early 20th century. Except for the U.S and the U.K, virtually all countries suffered from the "original sin" regime throughout the history before the 1970s, and even the US external sovereign debt had implicit or explicit gold clauses until 1933.

(U.K.), the Civil War, and the First World War (U.S.) were motivated to establish a trustworthy reputation with foreign lenders to maintain access to future loans for the next war.

Even under the *incomplete* asset market structure, however, a sovereign government can work out time-consistent optimal state contingent monetary and debt policy in a similar spirit to Lucas and Stokey (1983) and Chang (1998). The government can then announce the monetary and fiscal policy to foreign lenders and ask them to agree on the terms of contract featuring the policy. As long as foreign lenders get an expected return of R^*, risk-neutral lenders would accept the contract.

We interpret the sovereign borrower's adoption of a local currency contract with state contingent inflation rates as a commitment to inflation targeting. Svensson (1997) points out that a stronger commitment to a systemic monetary policy through inflation targeting, with increased transparency through communication with the public and increased accountability of the central bank, can mimic the optimal inflation contract offered to an independent central banker suggested by Walsh (1995).

In our model, targeting the exchange rate and targeting inflation (or, more precisely, the price level) are equivalent, given the assumption of the law of one price and the exogenous nominal price in the lending country. In the real world, those policies often have been perceived as being different. Exchange-rate targeting has often involved capital controls and sterilized intervention, and monetary policy has not been rigorously devoted to stabilizing inflation. The real appreciations that many exchange-rate peggers experienced was mostly not a result of rapid productivity gains in the traded sector that led to increases in the relative price of nontraded goods, but was more attributable to controls that fixed the exchange rate while allowing CPI inflation to continue. This was often reflected in black-market exchange rates which diverged from official pegged rates.[13] We interpret the adoption of inflation targeting as the recognition that the old policies, which did not target inflation, were untenable politically and in terms of economic welfare.

Value of Debasement

Due to the limited commitment (enforcement) of monetary policy, the sovereign government can debase its currency excessively at any time by choosing a higher inflation rate than $\pi(x_t)$ called for in the contract, in order to inflate away a certain fraction of local currency debt. When the government breaches the contract through excessive debasement, 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. The sovereign in the original sin regime cannot commit to any monetary and debt policy. In

[13] See, for example, Edwards (1989).

the original sin regime, we consider a Markov perfect equilibrium, in which the sovereign conducts discretionary monetary and debt policy, and defaults on its debt in equilibrium as in the standard quantitative sovereign debt literature (Aguiar and Gopinath (2006), and Arellano (2008)).[14]

The value of debasement is given by

$$V^{debase}\left(b_t^{for}, b_t^{loc}, y_{t-1}, y_t; i_t, \pi(x_t)\right) = \max_{\pi_t \neq \pi(x_t), c_t, b_{t+1}^{for}} \left[u(c_t) - C(\pi_t - \bar{\pi})\right] + \beta E_t V^o\left(b_{t+1}^{for}, y_{t+1}\right) \tag{8}$$

subject to the budget constraint:

$$c_t + q(b_{t+1}, y_t) b_{t+1}^{for} = y_t + R^* b_t^{for} + \frac{i_t b_t^{loc}}{\pi_t}, \tag{9}$$

$$b_{t+1}^{for} \geq -D. \tag{10}$$

$V^o(\ )$ denotes the value of the option to default in the original sin regime after the debasement. At the time of excessive debasement, the sovereign still needs to pay back fully the nominal amount of its local currency debt, but the debasement reduces the real repayment. The sovereign rolls over its debts-both local and foreign currency debts- with b_{t+1}^{for} at the discount bond price $q(b_{t+1}, y_t)$, which will be defined in the next subsection.

Value of Foreign Currency Borrowing (Original Sin Regime)

If a sovereign and lenders fail to agree on terms of local currency debt at period 0 (i.e., there exists no sustainable local currency debt contract (see Definition 1 below)), or if the sovereign breaches the local currency contract through excessive debasement at a later period, the economy must borrow only in foreign currency thereafter.

In the original sin regime, the sovereign can default on its debt at any time after comparing the values of default and no default. Upon default, the economy enters financial autarky, in which it temporarily loses access to foreign currency borrowing from international financial market.

The value of the option to default when the sovereign has access only to foreign currency borrowing is given by

$$V^o(b_t^{for}, y_t) = \max\{V^{for}(b_t^{for}, y_t), V_{for}^{def}(y_t)\}, \tag{11}$$

[14] In the previous version of this paper, we consider an equilibrium in which the sovereign does not default in equilibrium in the original sin regime. Allowing for equilibrium default does not result in any qualitative changes in simulation results of our model.

where V_{for}^{def} denotes the value of default, when the economy enters financial autarky from the foreign currency borrowing regime. The value of foreign currency borrowing for the case of no default is given by

$$V^{for}\left(b_t^{for}, y_t\right) = \max_{c_t, \pi_t, b_{t+1}^{for}} [u\left(c_t\right) - C(\pi_t - \overline{\pi})] + \beta E_t V^0\left(b_{t+1}^{for}, y_{t+1}\right) \ , \tag{12}$$

subject to the following constraints:

$$c_t + q(b_{t+1}^{for}, y_t) b_{t+1}^{for} = y_t + b_t^{for} \ , \tag{13}$$

$$b_{t+1}^{for} \geq -D \ . \tag{14}$$

The bond pricing function $q(b_{t+1}^{for}, y_t)$ is defined as follows:

$$q(b_{t+1}^{for}, y_t) = \frac{1}{R*} \sum_{y_{t+1} \in Y} \Pr(y_{t+1} \mid y_t) \mathrm{I}(V^{for}(b_{t+1}^{for}, y_{t+1}) > V_{for}^{def}(y_{t+1})) \ , \tag{15}$$

where I is an indicator function which takes on the value of one if the condition inside the parenthesis holds, and zero otherwise. With no local currency debt on hand, the optimal $\pi_t^* = \overline{\pi}$.

Value of Default

Upon default, the economy enters financial autarky for a stochastic number of periods, during which the economy loses access to international financial markets, and the economy suffers a drop in income. There are two types of financial autarky: one resulting from default in the original sin regime (the economy has lost both monetary and repayment reputation), and the other from default when the sovereign has a local currency contract (the economy lost only the repayment reputation). In both cases, the countries re-enter their respective credit markets with an exogenous probability θ, and start with zero debt.

The value of default when the economy enters financial autarky from the original sin regime is given by

$$V_{for}^{def}\left(y_t\right) = \max_{\pi_t}[u\left(c_t\right) - C(\pi_t - \overline{\pi})] + \beta(1-\theta) E_t V_{for}^{def}\left(y_{t+1}\right) + \beta\theta E_t V^o(0, y_{t+1}) \tag{16}$$

$$c_t = h\left(y_t\right), \tag{17}$$

where $h(y_t) < y_t$. $h(y_t)$ represents a decrease in income associated with financial autarky after default. As with the value of foreign currency borrowing, $\pi_t^* = \overline{\pi}$.[15]

The value of default when the economy enters financial autarky after default when the sovereign has a local currency contract is given by

$$V_{loc}^{def}(y_t) = \max_{\pi_t}[u(c_t) - C(\pi_t - \overline{\pi})] + \beta(1-\theta)E_t V_{loc}^{def}(y_{t+1}) + \beta\theta W(0,0,y_t) \ , \tag{18}$$

$$c_t = h(y_t), \tag{19}$$

where $W(.)$ is the value of local currency contract, which will be defined in the next subsection. We also have $\pi_t^* = \overline{\pi}$.

Original Problem under the Optimal Self-Enforcing Contract

We study an optimal self-enforcing contract in our model: 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 an incentive to breach the contract in any state of the world. The optimal contracting approach allow us to model inflation targeting as a committed monetary policy.

The original problem under the optimal self-enforcing contract is given by:

$$\max_{\left\{c_t, b_{t+1}^{for}, b_{t+1}^{loc}, \pi_t, i_t\right\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t \left[u\left(c_t\left(s^t\right)\right) - C\left(\pi_t\left(s^t\right) - \overline{\pi}\right)\right] \tag{20}$$

subject to (1) the budget constraint, (2) the enforcement constraint, (3) the expected zero profit condition for the lenders. $\left(y_{-1}, b_0^{for}, b_0^{loc}\right)$ are initially given.

$$c_t\left(s^t\right) + b_{t+1}^{for}\left(s^t\right) + b_{t+1}^{loc}\left(s^t\right) = y_t\left(s^t\right) + R^* b_t^{for}\left(s^{t-1}\right) + \frac{i_t\left(s^{t-1}\right) b_t^{loc}\left(s^{t-1}\right)}{\pi_t\left(s^t\right)} \tag{21}$$

[15] We have a counterfactual result that the economy without monetary commitment (original sin regime) has a perfectly stable inflation rate ($\pi_t = \overline{\pi}$)in equilibrium. In section 5, in which we extend the model to include the Phillips curve, we find that the economy without monetary commitment suffers from higher inflation than that with monetary commitment.

$$E_t \sum_{n=0}^{\infty} \beta^n \left[u\left(c(s^{t+n}) \right) - C\left(\pi(s^{t+n}) - \overline{\pi} \right) \right] \geq \max \left\{ V^{debase}(b_t^{for}, b_t^{loc}, y_{t-1}, y_t), V_{loc}^{def}\left(y_t \right), \right\}, for \ \forall \ \mathrm{s}^t, t \geq 0 \tag{22}$$

$$R^* = \sum_{y_t} Pr\left(y_t \mid s^{t-1} \right) \frac{i_t\left(s^{t-1} \right)}{\pi_t\left(s^t \right)} \tag{23}$$

Then, an equilibrium in this model is an infinite sequence of inflation and interest rates on local currency debt $\pi_t\left(s^t\right)$ and $i_t\left(s^{t-1}\right)$ in the contract, and allocations $\left\{c_t\left(s^t\right), b_{t+1}^{for}\left(s^t\right), b_{t+1}^{loc}\left(s^t\right)\right\}$ such that the contract and the allocations solve the maximization problem subject to the budget constraint (equation (21)), the enforcement constraint (equation (22)), and the lender's expected return condition (equation (23)).

Note that the enforcement constraint equation (22) has two value functions on the right hand side: the values of debasement and default. The enforcement constraint comes from two different types of limited commitment problems regarding the government's monetary and debt policy. These two enforcement frictions combine to generate an endogenous debt frontier, determining the maximum amount of debt in each currency. The debt frontier, in turn, affects the currency composition of sovereign debt, which will be discussed in detail in section 4.

Recursive Formulation of the Original Problem

Since the enforcement constraint equation (22) has expected values of future variables, we cannot use the standard recursive Bellman equation, as pointed out first by Kydland and Prescott (1977). This is a problem shared with many economic models with time-inconsistent government policy. Our original problem can be recast and solved 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 y_t is realized at period *t*, the optimal contract chooses a nominal interest rate i_t on the local currency debt b_t^{loc} and an ex-post inflation rate π_t (currency depreciation rate) for each state y_t for the period *t*, so as to maximize the expected sum of value functions V^c's.

$$W\left(b_t^{for}, b_t^{loc}, y_{t-1}\right) = \max_{i_t, \pi(x_t)} \sum_{y_t \in Y} Pr\left(y_t \mid y_{t-1} \right) V^c\left(b_t^{for}, b_t^{loc}, y_{t-1}, y_t; \pi\left(x_t\right), i_t \right) \tag{24}$$

subject to the lender's expected zero profit condition and the enforcement constraint:

$$R^* = \sum_{y_t \in Y} Pr\left(y_t \mid y_{t-1}\right) \frac{i_t\left(b_t^{for}, b_t^{loc}, y_{t-1}\right)}{\pi_t\left(b_t^{for}, b_t^{loc}, y_{t-1}, y_t\right)} \tag{25}$$

$$V^C\left(b_t^{for}, b_t^{loc}, y_{t-1}, y_t; \pi\left(x_t\right), i_t\right) \geq \max\left\{V^{debase}\left(b_t^{for}, b_t^{loc}, y_{t-1}, y_t\right), V_{loc}^{def}\left(y_t\right)\right\} \text{ for } \forall\ y_t \tag{26}$$

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

$$V^C\left(b_t^{for}, b_t^{loc}, y_{t-1}, y_t; \pi\left(x_t\right), i_t\right) = \max_{c_t, b_{t+1}^{for}, b_{t+1}^{loc}} \left[\left[u\left(c_t\right) - C\left(\pi_t - \bar{\pi}\right)\right] + \beta W\left(b_{t+1}^{for}, b_{t+1}^{loc}, y_t\right)\right] \tag{27}$$

$$c_t + b_{t+1}^{for} + b_{t+1}^{loc} = y_t + R^* b_t^{for} + \frac{i_t b_t^{loc}}{\pi\left(x_t\right)} \tag{28}$$

Following Atkeson (1991), Chang (1998), 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 *n,* the domain D_n of W_n and V_n is updated such that it solves the maximization problems of equations (24) and (27) subject to equations (25), (26), and (28). The sequences of $\{W_n\}$, $\{V_n\}$, and $\{D_n\}$ are decreasing, finally converging to *W*, *V*, and *D*. Then, we obtain combinations of $\left(b^{loc}, b^{for}\right)$ in *D* that satisfy the budget and enforcement constraints. Appendix F presents a detailed computation algorithm.

When the enforcement constraint (eq.(26)) is *not* binding at any x_t^i, we have the following first order conditions with respect to $\pi(x_t^i)'s$:

$$-u'\left(c\left(x_t^i\right)\right) i_t b_t^{loc} - C'\left(\pi\left(x_t^i\right)\right) \pi\left(x_t^i\right)^2 = -u'\left(c\left(x_t^j\right)\right) i_t b_t^{loc} - C'\left(\pi\left(x_t^j\right)\right) \pi\left(x_t^j\right)^2 \;, \tag{29}$$

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

The first term on the left hand side in eq. (29) is the marginal benefit of an increase in the inflation rate at the low income state $\left(x_t^i\right)$: an increase in inflation rates leads to a decrease in the real value of local currency debt $b_t^{loc} < 0$, thus increasing consumption at $\left(x_t^i\right)$. Note that the first term on the left hand side in eq. (29) has b_t^{loc}: The more local currency debt the economy holds at period *t*, the higher 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 state $\left(x_t^i\right)$.

If there is an increase in the inflation rate (i.e., currency depreciation) at the state $\left(x_t^i\right)$, the zero profit condition for the foreign lenders (eq.(25)) requires a decrease in inflation rates (i.e., currency appreciation) at other high income states $\left(x_t^j\right)$ to compensate for the loss incurred to the lenders at the low income state $\left(x_t^i\right)$.[16] At an optimum, the contract equates the marginal benefit of inflation net of the cost of inflation across states when the enforcement constraint is *not* binding at any x_t.

When the enforcement constraint (eq.(26)) is binding at the high income state $\left(x_t^j\right)$, we have the following inequality:

$$-u'\left(c\left(x^i{}_t\right)\right)i_t b_t^{loc} - C'\left(\pi\left(x_t^i\right)\right)\pi\left(x_t^i\right)^2 \geq -u'\left(c\left(x_t^j\right)\right)i_t b_t^{loc} - C'\left(\pi\left(x_t^j\right)\right)\pi\left(x_t^j\right)^2$$

This inequaility shows that when the enforcement constraint is binding at the high income state $\left(x_t^j\right)$, the monetary policy becomes restricted in providing sufficient consumption insurance at the low income state $\left(x_t^i\right)$. A further depreciation of the currency at the low income state $\left(x_t^i\right)$ requires an appreciation of the currency at the high income state $\left(x_t^j\right)$, which in turn, would violate the enforcement constraint at $\left(x_t^j\right)$.

The first order condition with respect to i_t is given by

$$\sum_{y^i{}_t \in Y} \Pr\left(y^i{}_t \mid y_{t-1}\right) C'\left(\pi_t\left(x_t^i\right)\right)\pi\left(x_t^i\right) = 0, \tag{30}$$

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 $\overline{\pi}$, the marginal cost at $\pi_t < \overline{\pi}$ is negative.

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

[16] As previously noted, the contract calls for "price-level targeting" rather than inflation targeting per se in the lingo of the literature on monetary policy rules.

Proposition 1: *Suppose that there is no cost of inflation (i.e., $C(\pi_t - \overline{\pi}) = 0$ for all π_t). Then, the optimal local currency contract under full commitment (i.e., no enforcement constraint eq (22)) can replicate the consumption allocation under complete assets market.*

Proof: See the Appendix.

With no cost of inflation and under the sovereign's full commitment, the optimal local currency contract completely smooths consumption of the representative household across states, thus replicating the consumption allocation under complete assets market.

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

$$\pi\left(x_t^i\right) > \pi\left(x_t^j\right) \tag{31}$$

The corollary shows that without any frictions, the optimal local currency contract 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 due to its state-contingency, especially when there is no cost of inflation.

Debt Frontier

We first define B^l, the maximum amount of local currency debt that can be sustained in any date and any state in equilibrium, and then the debt frontier $B^f\left(b^{loc}\right)$. For any combination of local and foreign currency debt $\left(b^{loc}, b^{for}\right)$ inside the frontier, the sovereign always honors its local currency contract.

B^l is defined as follows:

$$B^l \equiv \max_{y \in Y} \left\{\underline{b^{loc}}(y)\right\},$$

where $\underline{b^{loc}}\left(y\right) < 0$ is the maximum amount of local currency debt b_{t+1}^{loc} that can be sustained in equilibrium when today's income shock is *y*, and is defined as:

$$\underline{b^{loc}}(y) \equiv \max_{y'|\Pr(y'|y)>0} \left\{ b_{t+1}^{loc}(y') : V^c\left(0, b_{t+1}^{loc}(y'), y, y'\right) = \max\left[V^{debase}\left(0, b_{t+1}^{loc}(y'), y, y'\right), V_{loc}^{def}(y') \right] \right\} \tag{32}$$

That is, $\underline{b^{loc}}(y)$ is the maximum amount of the local currency debt that does not violate the enforcement constraint under *all* possible future contingencies for the next period (i.e., for all y' with $\Pr(y'|y) > 0$), given that the current income shock is y, and that the sovereign does not borrow in foreign currency (i.e., $b_{t+1}^{for} = 0$). For any more local currency borrowing than $\underline{b^{loc}}(y)$ (i.e., $b_{t+1}^{loc} < \underline{b^{loc}}(y)$), the sovereign would be tempted to default or to excessive debasement for a certain income shock y' in the next period (i.e., the right hand side of the equation (32) is greater than the left hand side), so that it would not be sustainable and not allowed in the contract.

Then $B^l < 0$ is the maximum amount of the local currency borrowing with $b_{t+1}^{for} = 0$ without violating the enforcement constraint at any date and any state.

Debt frontier $B^f\left(b^{loc}\right)$ is defined in the following:

$$B^f\left(b^{loc}\right) \equiv \max_{y \in Y} \left\{ \underline{b^{for}}\left(b^{loc}, y\right) \right\}, \; for \; B^l \le b^{loc} \le 0 \;,$$

where $\underline{b^{for}}\left(b^{loc}, y\right)$ is defined in the following:

$$\underline{b^{for}}\left(b^{loc}, y\right) \equiv \max_{y'|\Pr(y'|y)>0} \left\{ b_{t+1}^{for}(y') : V^c\left(b_{t+1}^{for}(y'), b^{loc}, y, y'\right) = \max\left\{ V^{debase}\left(b_{t+1}^{for}(y'), b^{loc}, y, y'\right), V_{loc}^{def}(y') \right\} \right\},$$

$$\text{for } B^l \le b^{loc} \le 0 . \tag{33}$$

That is, $\underline{b^{for}}\left(b^{loc}, y\right)$ is the maximum amount of foreign currency borrowing which satisfies the enforcement constraint under all possible future contingencies, given that the economy chooses to borrow $b_{t+1}^{loc} = b^{loc}$ in local currency for the current income shock y. Any more borrowing than $\underline{b^{for}}\left(b^{loc}, y\right)$ (i.e. $b_{t+1}^{for} < \underline{b^{for}}\left(b^{loc}, y\right)$) in foreign currency violates the enforcement constraint for some y' in the next period, so is not sustainable in equilibrium.

For any combinations of local and foreign currency debt $\left(b^{loc}, b^{for}\right)$ inside the debt frontier $B^f(b^{loc})$, 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 the no default borrowing constraint in Zhang (1997) and the solvency constraints in Alvarez and Jermann (2000).

Definition 1: *If* $\underline{b}^{loc}(y)=0$ *for all* $y \in Y$ *in equilibrium, there exists no sustainable local currency debt contract in equilibrium.*

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 $y \in Y$. This refers to the situation that a sovereign and lenders fail to agree on terms of a local currency debt contract at period 0, so that a sovereign must borrow in foreign currency thereafter in equilibrium, given that foreign currency borrowing exists. It must be noted that this case is different from the original sin regime into which the economy falls as punishment after excessive debasement.

Proposition 2: *For sufficiently small values of* β, *sufficiently low costs of inflation, and sufficiently high output costs of default, there exists no sustainable local currency debt contract in equilibrium, so that the economy must borrow in foreign currency from period 0 onward.*

Proof: See the Appendix**.**

If a sustainable local currency contract cannot be constructed, the economy must borrow in foreign currency from period 0 onward.[17] This proposition indicates the characteristics of a country that determine the extensive margin of local currency borrowing; that is, which countries can obtain a local currency contract with lenders, and which countries cannot so that they must suffer from the original sin.

This proposition shows that even when local-currency debt contracts offer the opportunity for the sovereign borrower to use inflation/depreciation to smooth consumption risk, there are circumstances under which it will not be able to credibly commit to a local-currency debt contract. When inflation costs are low, the gain from a consumption increase through ex-post excessive debasement is high. Moreover, when the time discount factor β is low, the sovereigns put little value on the future continuation value from following contract. In this case, the sovereigns find it optimal to breach the contract through excessive debasement and must borrow in foreign currency. Note that we need a sufficiently high value of output cost of default to support a positive amount of foreign currency debt in equilibrium. That is, if the output cost of default is

[17] Ottonello and Perez (2019) show that the local currency debt market shuts down only when the cost of inflation is zero. In our model, it is possible that the local currency debt is sustainable in equilibrium without a cost of inflation. When the economy is very risk-averse and/or patient, and/or its income shock process is very volatile, the economy would put more value on the continuation value from the local currency contract than on an increase in current consumption from excessive debasement. Our model has a different prediction because our model considers a committed monetary policy with commitment frictions, whereas Ottonello and Perez (2019) considers a discretionary monetary policy with the same frictions. Phan (2017) also shows that the local currency debt can be sustainable in equilibrium without any cost of inflation if certain conditions hold.

zero or very small, the sovereign would always default on foreign currency debt, so that there would be no original sin regime in equilibrium.

The sovereigns that have low continuation value from following the contract and have low inflation costs find it optimal to breach the contract through excessive debasement and must borrow in foreign currency.

In the quantitative analysis in section 4, we show that a country's monetary credibility, represented by its cost of inflation, mainly accounts for the intensive margin of local currency borrowing (i.e., how much a country can borrow in local currency.)

Corollary to Proposition 2 (No Existence of Original Sin) : *Suppose that foreign currency borrowing exists, and that the cost of inflation is greater than zero. If breach of contract through excessive debasement is punished by financial autarky as with outright default on debt, then there always exists a sustainable local currency debt contract, so that the economy can borrow in local currency from period 0 onward.*

The proof is straightforward. If breach of contract by excessive debasement is punished by financial autarky, the value of debasement is strictly less than the value of default, when the cost of inflation is greater than zero. Then, local currency debt has no debasement risk. In this case, the sovereign and lenders can agree on a local currency debt contract in which inflation rates are set to the target inflation rate $\overline{\pi}$ for all states. As long as foreign currency borrowing exists, this local currency debt contract can be sustainable in equilibrium.

That is, if both outright default and excessive debasement are equally punished by financial autarky, there will be no economy that borrows only in foreign currency in equilibrium. This implication is clearly at odds with the data since many EM economies still cannot borrow in their own currency. In Appendix D, we conduct a counterfactual analysis in which the equal punishment of financial autarky is imposed on the economy, whether it breaches the local currency contract with excessive debasement or outright default. We find that the degree of monetary credibility has little effect on how much a sovereign can borrow in local currency in this case.

There is a mix of foreign and local currency debt in equilibrium because default is generally more costly than excessive debasement. Because of the higher cost from default, foreign currency debt has more credibility than local currency debt, thus allowing the sovereign to borrow more in foreign currency as a substitute for monetary credibility. Foreign currency debt is valuable for its credibility associated with high cost of default, whereas local currency debt is valued for its state contingency.

Another advantage of local-currency debt that the literature on EM imbalances has addressed is the elimination of "currency mismatch". That is, when debt is denominated in foreign currency, there may be a mismatch between the currency of denomination of liabilities and assets (which for governments are in the form of tax revenues), and these are known to create sources of vulnerability in EM countries. These do not play a role in our model because of the assumptions of the law of one price and flexible prices, but in a richer model may provide an additional benefit of local-currency denominated debt.

Proposition 3: *Suppose that the cost of inflation is zero for all* π_t. *Then the equilibrium nominal interest rate for local currency debt* i_t *is indeterminate*.

The proof is straightforward and is from the lender's expected zero profit condition equation (25). With no cost of inflation, the real interest rate on local currency debt i_t / π_t only matters for the equilibrium allocations.

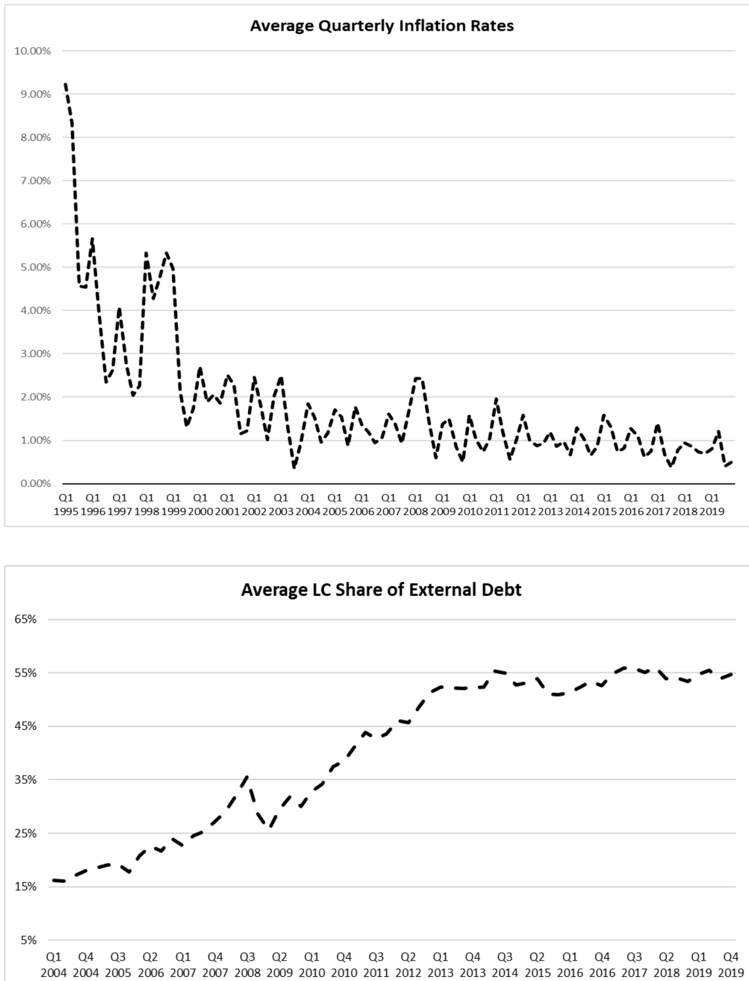
Proposition 4: *If* $C\left(\pi_t - \overline{\pi}\right) = \infty$ *for any* $\pi_t \neq \overline{\pi}$, then $\pi_t\left(s^t\right) = \overline{\pi}$ for all *t*. *Moreover, the currency composition between foreign and local currency debts is indeterminate.*

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.

4. Quantitative Results

Figure 4: Inflation Performance and LC share of External Debt for EM Economies



Note: The top panel plots the average quarterly inflation rates for nine EM economies: Brazil, Colombia, Hungary Indonesia, Mexico, Poland, Russia, South Africa, and Thailand. The data source is IFS. The bottom panel plots the average quarterly local currency share for the nine EM economies. The data source is Arslanalp and Tsuda (2020).

After having suffered high inflation throughout the 1980s and 1990s, a number of EM economies adopted inflation targeting after 2000. The top panel of Figure 4 plots the average quarterly inflation rates from 1995Q1 through 2019Q4 for nine EM economies[18]. Since the adoption of inflation targeting, EM economies' inflation rates have been stabilized. (Fraga, Goldfajn, and Minella (2003)). On the other hand, the local currency share of EM economies' sovereign debt steadily increased since 2001 and took off around 2010. Since then, the LC share has been stable at around 55%. (The bottom panel of Figure 4).

[18] These nine countries adopted inflation targeting as their main monetary policy after 2000, and they all have available seasonally adjusted quarterly data for GDP and CPI for the period since 2000.

In this section we calibrate the model to a panel of EM economies to provide quantitative answers to two empirical questions regarding the EM's local currency borrowing: (1) What accounts for time and cross-country variations of local currency borrowing of EM economies, and (2) the mystery of original sin as shown in section 2- the fact that standard measures of economic performance do not account for the ability of countries to borrow in domestic currency?

Table 2: Model Parameters

Parameters from Literature	Value	Descrption	Source/ Target Moment
γ	5	Risk aversion	Literature
r_f	1%	Quarterly risk free rate	Literature
θ	1/40	Prob of re-entry to credit market	Uribe and Schmitt-Grohé (2017)
Parameters Directly Estimated from Data			
σ_ϵ	0.018	Std of income	EM's GDP Series (1994Q1-2019Q4)
ρ	0.740	Persistence of income shock	EM's GDP Series (1994Q1-2019Q4)
Calibrated Parameters			
β	0.978	Time discount factor	$corr(\Delta Y_t, \pi_t)$
ξ	0.117	Cost of inflation	Volatility of inflation
λ	0.61%	Output cost of default	Debt to GDP ratio

Table 3-1: Target Moments (Data Vs. Simulated Moments)

Description	Empirical Moments (2010Q1-2019Q4)	Simulated Moments
Std of Inflation Rate (%)	0.77%	0.78%
$corr(\Delta Y, \pi)$	-0.511	-0.811
External Government Debt (% of GDP)	15.9%	15.7%

Table 3-2: Non-Target Moments (Data Vs. Simulated Moments)

Description	Empirical Moments (2010Q1-2019Q4)	Simulated Moments
LC Share (%)	50.17%	37.47%
$corr(\pi_{t-1},\pi_t)$	0.217	-0.001
$corr(Y, LC\ share)$	0.108	0.632
$corr(\Delta C,\pi)$	-0.10	-0.70
$corr(TB/Y, Y)$	0.018	0.65
$\sigma(TB/Y)$	1.63	1.05

Note: *Y, C,* and π respectively denote the real GDP, consumption, and a quarterly inflation rate. $\boldsymbol{\Delta Y}$ ***and*** $\boldsymbol{\Delta C}$ respectively denote the growth rates of real GDP and consumption. TB/Y denotes the trade balance to GDP ratio. All the data except for $\boldsymbol{\Delta Y}$ ***and*** $\boldsymbol{\Delta C}$ are detrended with the HP filter with a smoothing parameter of 1600. For the correlation between Y and LC share, the sample period is 2004Q1-2019Q4. The data sources for TB and external government debt are respectively IFS and World Bank's WDI. The empirical moments are the average of those for the nine countries.

4.1 Parameters and Functional Forms

The benchmark calibrates the model to an average of the nine EM economies. Table 2 reports parameter values employed or calibrated for our main benchmark calibration. A period is a quarter. We use a CRRA utility function of the form $(c^{\gamma-1}-1)/(1-\gamma)$ and set the risk aversion coefficient γ to be five, which is within the range of values used in the literature. The quarterly risk-free rate r_f is set to be 1%. The probability of re-entry from financial autarky to the credit market θ is set to be 1/40 (i.e., the average autarky period is 10 years) from Uribe and Schmitt-Grohé (2017), which finds that the autarky period for defaulting countries ranges from 4 to 15 years.[19] We choose the sample period to be from 2010Q1 through 2019Q4, because these nine EM economies adopted inflation targeting before 2010, and their LC shares have been stable since 2010.

- The stochastic process for output is estimated using HP detrended GDP series for the EM economies from 1994Q1 to 2019Q4. It is assumed to be a log-normal AR(1) process : $\log(y_t)=\rho\log(y_{t-1})+\epsilon_t$ with $E[\epsilon_t]=0$ and $E[\epsilon_t^2]=\sigma_\epsilon^2$. The mean values for the nine EM economies are $\rho=0.741$ and $\sigma_\epsilon=0.018$.

[19] In Appendix D, we conduct a robustness check with respect to θ .

- We use a quadratic cost of inflation given by

$$C(\pi - \bar{\pi}; \xi) = \xi(\pi - 1)^2 , \qquad (34)$$

which implies that the target gross inflation rate $\bar{\pi}$ is normalized to be one.[20]

- The cost of default during autarky is a fraction λ of income:

$$h(y_t) = (1 - \lambda) y_t \qquad (35)$$

The remaining three parameters - the time discount factor β, the cost of inflation parameter ξ, and the output cost of default parameter λ - are calibrated to jointly match three empirical moments, each of which is the average of those for the nine EM economies: the standard deviation of quarterly inflation rates, the correlation between the growth rate of GDP and inflation rates, and the mean total external government debt to GDP ratio (Table 3-1).[21] Our model generates more strongly countercyclical inflation compared to the data. In the model, policymakers control inflation with only the intent of using inflation to smooth consumption through the change in real values of local currency debt. That is, in this simple model, there is no tradeoff, for example, between inflation and the output gap.

[20] Since the target inflation rate $\bar{\pi}$ is normalized to be one and a deviation in inflation rates from $\bar{\pi}$ incurs utility cost, our model is designed to account for the fall in inflation volatility, not the decrease in the level of inflation.

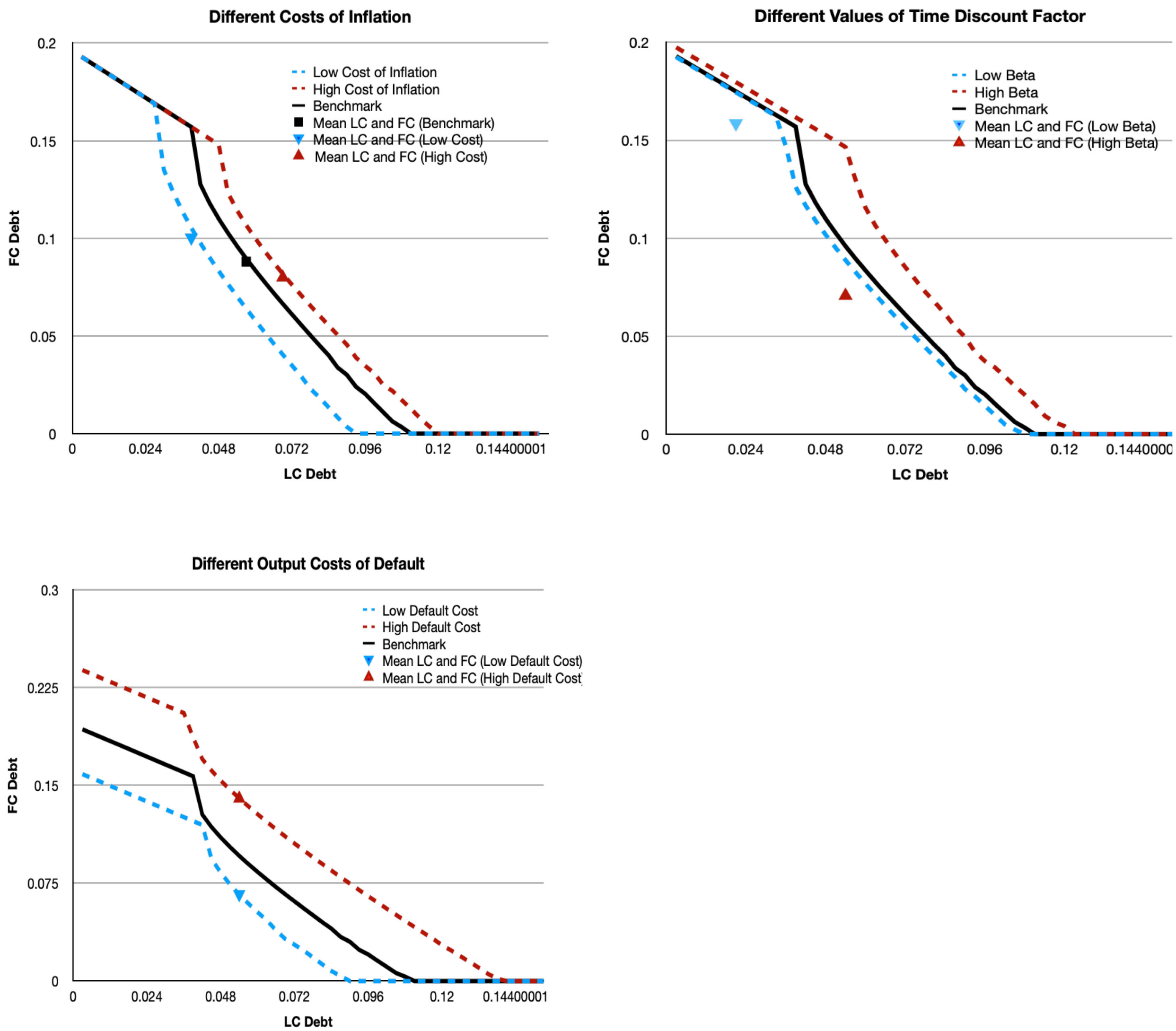
[21] The parameters are identified because they have different quantitative and qualitative implications for the three target moments. See table 4, which shows how the simulated moments change with a change in each parameter. A detailed discussion is in Appendix C.

Table 4: Comparison of Simulated Moments across Different Parameter Values

Description	Data	Benchmark	Low Inflation Cost ($\xi = 0.05$)	High Inflation Cost ($\xi = 0.20$)	Low Beta ($\beta = 0.97$)	High Beta ($\beta = 0.985$)	Low Default Cost ($\lambda = 0.5\%$)	High Default Cost ($\lambda = 0.75\%$)
B^l (% of GDP)	N.A	10.50%	8.70%	11.40%	10.20%	11.70%	8.40%	13.50%
Mean LC Share (%)	50.18 %	37.47%	24.97%	42.45%	11.00%	42.61%	42.94%	26.86%
Mean Total Debt (% of GDP)	15.97%	15.68%	15.64%	15.66%	17.79%	12.32%	12.26%	20.16%
$corr(Y, LC\ share)$	0.108	0.632	0.637	0.678	0.858	0.397	0.667	0.656
$corr(\Delta Y, \pi)$	-0.511	-0.811	-0.680	-0.708	-0.685	-0.692	-0.892	-0.685
$corr(\Delta C, \pi)$	-0.100	-0.701	-0.519	-0.561	-0.590	-0.595	-0.850	-0.524
$corr(TB/Y, Y)$	0.018	0.659	0.659	0.658	0.539	0.752	0.661	0.656
$corr(\pi_{t-1}, \pi_t)$	0.218	-0.001	-0.009	0.002	-0.008	-0.021	-0.008	-0.003
$\sigma(\pi_t)$ (%)	0.77%	0.78%	1.24%	0.55%	0.54%	0.76%	0.81%	0.85%
$\sigma(TB/Y)$ (%)	1.63%	1.05%	1.07%	1.05%	0.63%	1.48%	1.04%	1.07%

Note: This table compares the simulated moments of the benchmark model with those of the model with a different parameter value. We change only one parameter at a time with all the other parameter values fixed at those from the benchmark calibration. Total debt refers to the external public debt.

Figure 5 : Debt Frontiers with Different Parameter Values



Note: Figure 5 compares the debt frontier of the benchmark model with that of the model with a different parameter value. The black rectangle denotes the mean amounts of local and foreign currency debts for the benchmark model from the simulation. The triangle whose color is the same as that of a debt frontier denotes the mean amounts of local and foreign currency debts for the simulated model associated with the debt frontier.

4.2 Simulation Results

Table 3-2 compares the simulated moments with the empirical moments *not* targeted in the calibration.[22] Our model well matches the local currency share of external debt, even though it is simple and stylized: The simulated LC share is 37.4%, accounting for around 75% of its empirical counterpart (50.17%). Moreover, the simulated moments are qualitatively consistent with the empirical moments. Both GDP and consumption are negatively correlated with inflation, the correlation between GDP and inflation is more negative than that between consumption and inflation, and the trade balance is procyclical[23]. Our model also captures the observed procyclicality of the local currency share of debt, which was first documented by Ottonello and Perez (2019) and studied with a different model in that paper.

Table 4 compares the simulated moments from the benchmark model with those from the model with different parameter values. We change only one parameter at a time, with all other parameters fixed at the benchmark values.

Different Costs of Inflation

The fourth and fifth column of the Table 4 respectively report the simulated moments for the cases of low and high costs of inflation ($\xi = 0.05$ vs $\xi = 0.20$). The top panel of Figure 5 shows the debt frontiers for the respective cases. The debt frontier $B^f\left(b^{loc}\right)$ displays the maximum debt limits for both types of debts supported in equilibrium without violating the enforcement constraints under all future contingencies. For any combination of (b^{loc}, b^{for}) inside the debt frontier, a sovereign honors its debt contract with foreign investors at any time and any state.

For the case of high inflation cost, the maximum local currency debt limit B^l is 11.40% of GDP, whereas for the case of the low inflation cost, B^l is 8.70%. That is, a high cost of inflation is associated with a more relaxed borrowing limit for the local currency debt. The average total debt – the sum of local and foreign currency debt in real terms – for both cases is quite similar at around 15%. The average LC share in total debt, however, shows a significant difference between the two cases: The LC share for the

[22] We simulate the model 6000 times (6000 quarters), and the first 1000 simulated data points are removed to rule out any effects of initial conditions. The simulated moments are the averages over the 5000 simulated data points.
[23] The simulated trade balance is more procyclical than its empirical counterpart. Our endowment economy model abstracts from investment, which is key to generating counter-cyclicality of trade balance for small open economies models, and excessive procyclicality is a common problem with RBC models that do not include investment. Either adding investment or moving toward a Keynesian model would help, but our intuition is that those features would not alter the basic mechanism at work in our model.

economy with a high cost of inflation is 42.45%, compared to 24.97% for the economy with a low cost of inflation.

Since the sovereign with a low cost of inflation can easily take advantage of the hedging benefit of local currency debt, it wants to borrow more in local currency. On the other hand, the sovereign with a low cost of inflation (thus less credible in terms of monetary policy) faces a high degree of temptation to excessive depreciation, so that foreign investors' unwillingness to lend in local currency is reflected in the debt frontier. Since the sovereign cannot borrow as much as it wants in local currency, it needs to rely on foreign currency debt to satisfy its borrowing need. Thus, in equilibrium, we see a mix of local and foreign currency debt in the sovereign debt portfolio.

The sovereign with a high cost of inflation can borrow more in both foreign and local currency than the sovereign with a low cost of inflation. Figure 5 shows that its debt frontier is larger than, and covers that of the low cost of inflation borrower. But for the sovereign with a high cost of inflation, taking advantage of the hedging benefit of local currency debt is costly, so it uses inflation less actively than the sovereign with a low cost of inflation. The lower volatlity of inflation for the sovereign with a high cost of inflation shows this point.

Different Values of Time Discount Factor

The sixth and seventh column of the Table 4 respectively report the simulated moments for the cases of low and high values of the time discount factor ($\beta = 0.97$ vs. $\beta = 0.985$). The middle panel of Figure 5 shows the debt frontiers for the respective cases. A sovereign with a high value of beta (more patient) can borrow more in both local and foreign currency, as it has a higher future continuation value than the sovereign with a low value of beta. It has less temptation to breach the contract through either outright default or excessive debasement. Even if the patient sovereign can borrow more in both currencies, the *equilibrium* amount of total debt is much less than that for the impatient sovereign (12.32% of GDP for the patient vs 17.79% for the impatient), because the patient sovereign prefers less front-loading of consumption. The patient sovereign faces a more relaxed debt frontier, and it borrows mainly in local currency. Unlike the case with a high cost of inflation, the patient sovereign will want to take advantage of the hedging benefit of local currency debt, thus actively using inflation to smooth its consumption. It follows that inflation is more volatile for the sovereign with a high value of beta than that with a low value of beta.

Different Output Costs of Default

The last two columns of Table 4 report the simulated moments for the cases of low and high output costs of default. The bottom panel of Figure 5 shows the debt frontiers for the respective cases. The change in the output cost of default directly affects the value of default, and it indirectly affects the value of debasement, because it affects the value of foreign currency borrowing. An increase in output cost of default enlarges the debt frontier, thus increasing a sovereign's overall borrowing capacity. Hence, the sovereign with a high default cost has a larger amount of total debt in equilibrium (20.16% vs 12.26%). The increase in output cost of default, however, relaxes the borrowing limit substantially more for foreign currency than for local currency. That is, the output cost of default has more influence on the borrowing limit for foreign currency. This leads the sovereign with a high default cost to borrow more in foreign currency.

4.3 Dynamic Analysis: Accounting for Time-variation of LC Share

Table 5-1: Comparison of Empirical Moments for Pre-2010 and Post-2010 periods

Description	**Empirical Moments (1994Q1-2009Q4)**	**Empirical Moments (2010Q1-2019Q4)**
Std of Inflation Rate (%)	2.59%	0.77%
$corr(\Delta Y, \pi)$	-0.406	-0.511
External Government Debt (% of GDP)	16.0%	15.9%
LC Share	22.68%	50.17%

Table 5-2: Data Vs. Simulated Moments for the pre-2010 period

Description	**Empirical Moments (1994Q1-2009Q4)**	**Simulated Moments**
Std of Inflation Rate (%)	2.59%	2.58%
$corr(\Delta Y, \pi)$	-0.406	-0.706
External Government Debt (% of GDP)	16.0%	16.1%
LC Share[24]	22.68%	9.33%

[24] LC share is not a target moment.

Table 6: Comparison of Deep Parameters between the Two Periods.

Description	Benchmark Values	Pre-2010 Period
ξ (Cost of inflation)	0.117	0.0098
β (Time discount factor)	0.980	0.977
λ (Output cost of default)	0.0060	0.0061

In our model, an EM's signing a local currency contract with lenders is interpreted as their adopting inflation targeting as their monetary policy. After having signed the contract, they are able to borrow in local currency (the extensive margin of local currency borrowing). In this section, we use our model to investigate what drives the increase in LC share over time after EM's adoption of inflation targeting (the intensive margin of local currency borrowing). Specifically, we examine which deep parameters account for time-variation of LC share by re-calibrating the model to the data[25] for the period before 2010.

Table 5-1 compares the main empirical moments between two time periods (1994Q1-2009Q4 and 2010Q1-2019Q4). Before 2010, EM's inflation is much more volatile, inflation is less countercyclical, and the LC share is much lower than that for the period since 2010. However, the external debt to GDP ratios are almost the same for both periods. We re-calibrate the three deep parameters- ξ, β, and λ to the same target moments for the pre-2010 period. All other parameters are fixed at the benchmark values.

Table 6 compares the deep parameters calibrated for the two different periods. The calibrated values for β and λ are almost the same for the two cases. On the other hand, the value of the cost of inflation ξ for the benchmark calibration (0.117) is more than 10 times greater than that for the pre-2010 calibration (0.0098). That is, based on our calibration, the increase in LC share over time is almost exclusively accounted for by the increase in the cost of inflation.

[25] As with the benchmark calibration, these moments are the average values for those for the nine countries.

Figure 6: Sensitivity Analysis w.r.t Cost of Inflation (ξ)

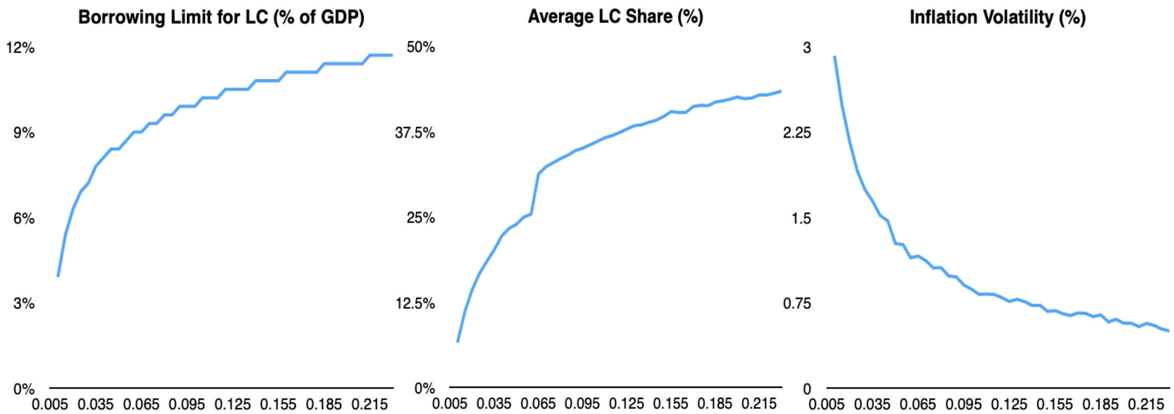


Figure 6 plots maximum local currency borrowing limits B^l, average local currency shares of sovereign debt, and inflation volatilities from the simulated models for different values of the cost of inflation parameter ξ ranging from 0.005 through 0.225, holding other parameters at those from the benchmark simulation. As the cost of inflation increases, the economy can borrow more in local currency (the left panel of the figure 6). The average LC share of the sovereign debt increases because the cost of inflation is the same regardless of the amount of local currency debt, but the benefit from consumption smoothing through inflation increases with the amount of local currency debt. As the cost of inflation increases, inflation volatility decreases.

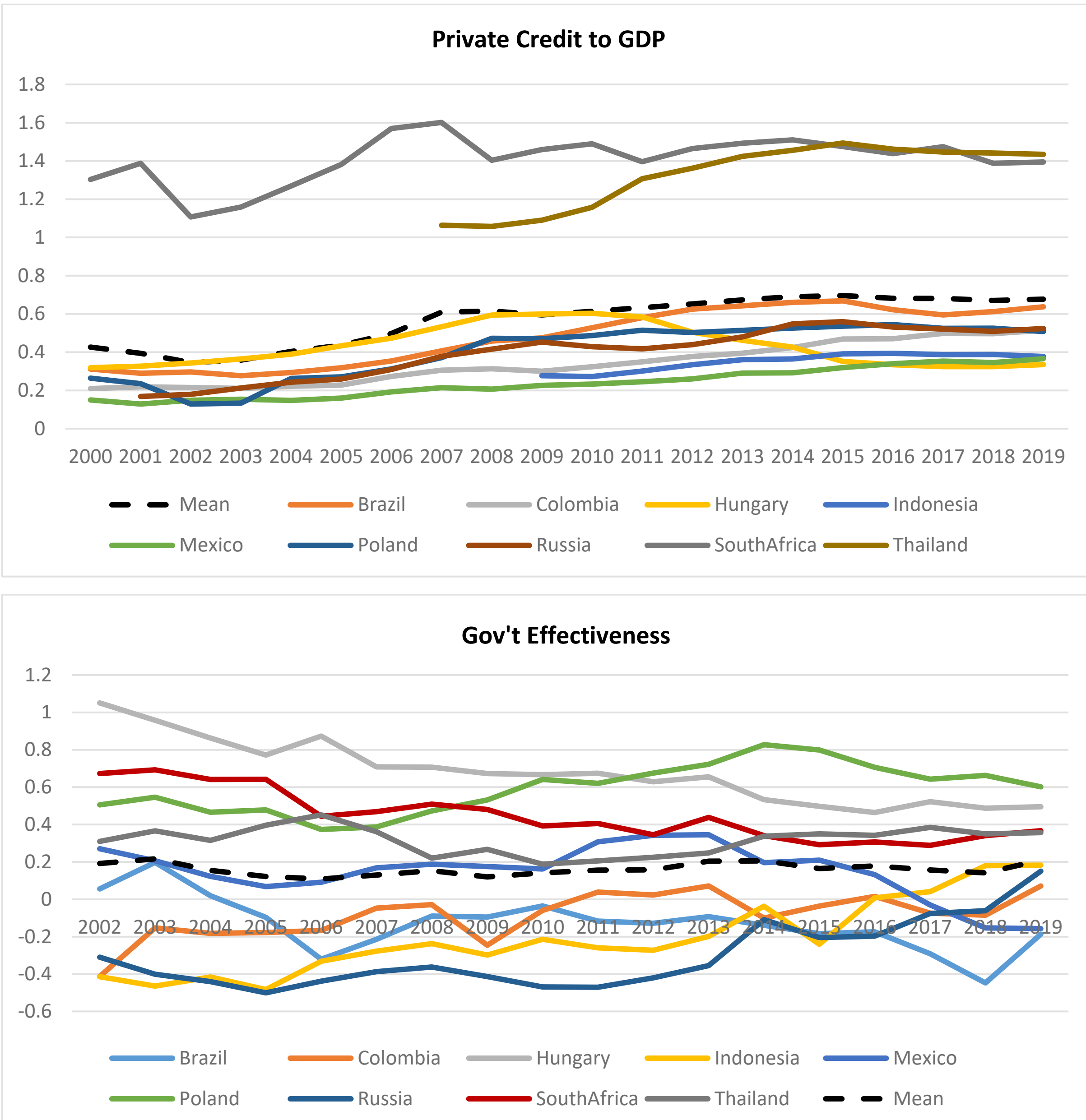
Inflation costs in these countries may have risen for a number of reasons: an increase in the political cost of inflation; central banks have gained more independence and the policy objective puts more weight on inflation; central bank policymakers have learned more about the welfare costs of inflation. If the loss function for the policymaker includes a term such as $C\left(\pi_t - \bar{\pi};\xi\right)$, as in our model, then the "targeting rule" puts a higher weight on deviations of inflation from its target as ξ increases. This is true whether or not the objective function is derived from underlying preferences, as in Woodford (2003). A targeting rule sets the monetary policy instrument to achieve a specific criterion for variables in the loss function.[26] The literature on optimal monetary policy demonstrate that a higher value of ξ leads to a rule with stricter inflation targeting.[27] We interpret the increase in the cost of inflation as the increase in the degree of monetary credibility for those countries which adopted inflation targeting as their monetary policy.

[26] See Svensson (2002) or Giannoni and Woodford (2017).
[27] See Clarida et al. (1999), Walsh (2003), Gali (2008).

Whereas Proposition 2 characterizes which country can adopt a credible monetary policy so that it can borrow in local currency (the extensive margin of LC borrowing), Figure 6 shows that the degree of monetary credibility represented by the cost of inflation parameter ξ mainly determines the intensive margin of local currency borrowing over the last decade.

The prediction of the model in Figure 6 is consistent with the dynamics of inflation and LC share in Figure 4. The emerging economies whose monetary policy has become increasingly more credible after having adopted inflation targeting in early 2000s managed to borrow more in local currency during the last decade. Their inflation rates have been stabilized in tandem with increased local currency debt.

Figure 7: Timeseries Plot of Domestic Credit/GDP and Gov's Effectiveness



4.3.1 Link to the Empirical Analysis

We relate the three deep parameters to empirical counterparts that were found to be statistically significant in accounting for a country's LC share in the regression in section 2.1. First, an increase in a country's cost of inflation ξ is associated with the increase of monetary credibility for EM's. Second, as an empirical counterpart for the output cost of default λ, we use the ratio of the amount of domestic credit to the private component of GDP, which measures the degree of financial development of a country. The sovereign default literature points out that sovereign default negatively affects aggregate output mainly through its effect on the financial sector – the more developed or complex a country's financial market is, the more damage sovereign default would likely cause to aggregate output. Finally, as an empirical counterpart for β, we use the index of government effectiveness. Hatchondo et al. (2009) show how the stability of the government in power mimics the effects of a more patient borrower.

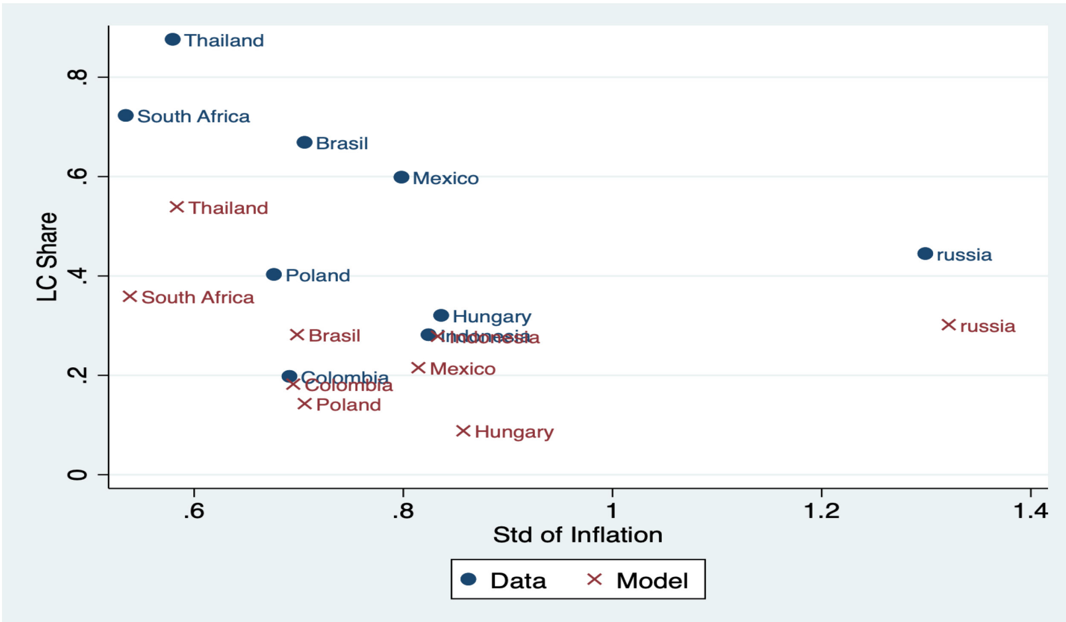
Monetary Credibility

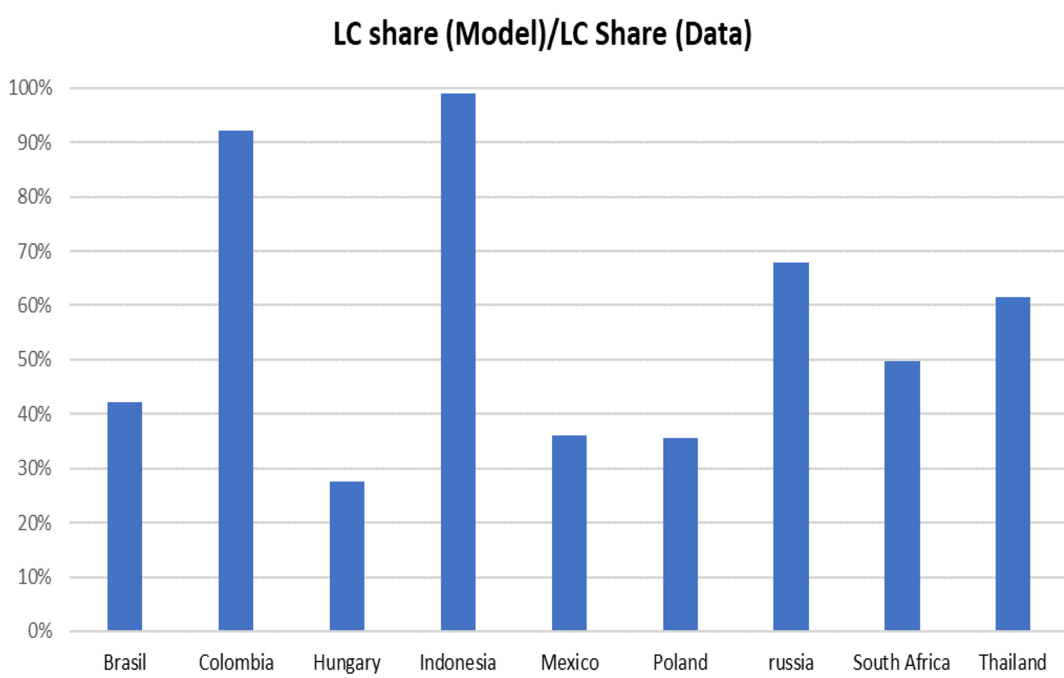
Fraga, Goldfajn, and Minella (2003) suggest that even though the adoption of inflation targeting for EM's succeeded in taming their inflation in early 2000's, their monetary policy is not immediately successful because of a low level of perceived credibility of the policy change. Building up credibility takes time. Alpanda and Honig (2014) show that inflation targeting is more effective when central banks are more independent for EM economies, and Jones and Matthijs (2019) argue that the degree of independence for most central banks has increased over the last decade. These studies are consistent with our model's explanation for the time variation of LC share for EM economies: EM's credibility in monetary policy accounts for most time variation of LC share.

Output Cost of Default and Time Discount Factor

The top panel of Figure 7 shows the time series plot of the ratio of the amount of domestic credit to the private component of GDP for the nine EM economies under study. On average, it slightly increased from 2000 but it has stayed at around 0.6 since 2007, which is consistent with our model's prediction. (The dashed black line denotes the mean value.) The bottom panel of Figure 6 shows the time series plot of the degree of government's effectiveness over time. As consistent with our model's prediction, it has stayed at around 0.2 over the sample period.

Figure 8: Comparison of Model and Data (LC share-Std of Inflation)





4.4 Cross-Country Analysis: Accounting for Cross-Country Variation of LC Share

What accounts for the cross-country variation of LC shares? To answer this question, we calibrate the model to *each* of the nine countries in the sample. Appendix B presents tables for estimated parameters and simulated moments for these countries. The top panel in Figure 8 plots the pairs of the standard deviation of inflation and LC share from the data and model simulation. The blue dot denotes a pair of inflation volatility and LC share from the data, and the red cross that from the simulation. The bottom panel shows the percentage of the simulated LC share over that of the data for the nine countries. The percentage ranges from 27.55% (Hungary) to 98.93% (Indonesia), and its average is 56.80%. Even though our model absents from many factors determining EM's local currency borrowing in the real world, it accounts for a significant fraction of the EM economies' LC share in the external sovereign debt.

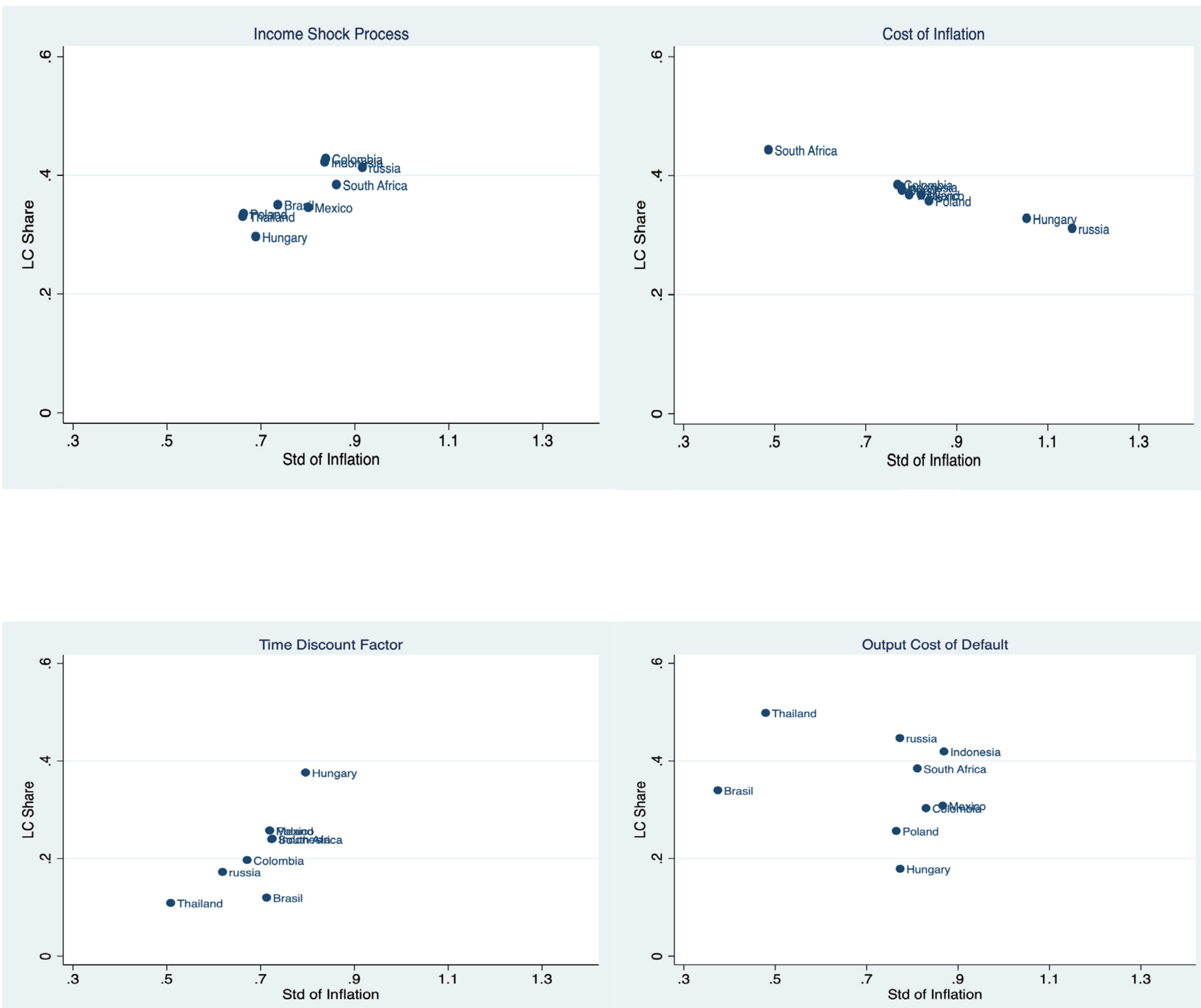
Our model does not include the country's bond market liquidity, differing degrees of local bond market development, and different institutional qualities, all of which might affect the pattern of international borrowing. Chan et al (2012) documents these factors for Asian countries in relation to the Asian Bond Market Initiative, which was aimed at having the ASEAN countries issue government debt in their own currency. Our model also does not include the Philips curve tradeoff between inflation and the output gap investigated in the section 5. Finally, due to the assumptions of purchasing power parity and flexible prices, our model cannot capture balance-sheet effects resulting from the currency mismatch, which can affect EM's local currency borrowing.

In the dynamic analysis section above, we show that the cost of inflation parameter (ξ) as a proxy for a country's monetary credibility almost exclusively accounts for the increased LC share of EM countries over time. Then which deep parameter drives most of the observed variation of LC share across countries since 2010? To answer this question, we change only one parameter at a time holding other parameters fixed at those from the benchmark calibration. This exercise can shed light on what is behind the cross-country variation of LC share and the mystery of original sin.

The top left panel in Figure 9 plots the simulated pairs of the LC share and inflation volatility for the countries in the sample when we *only* use the estimated income shock process for each country, holding the other parameters fixed at those from the benchmark calibration. The top right panel, bottom left panel, bottom right panel, respectively, plot the pairs when we only allow for the difference in the calibrated cost of inflation (ξ), the time discount factor (β), and the output cost of default (λ) across countries, holding the other parameters fixed at those from the benchmark calibration.

Along with the change in the income shock process and the time discount factor, the LC share and inflation volatility move in the same direction in simulation. On the other hand, along with the change in the cost of inflation, the LC share and inflation volatility move in the opposite direction. This result shows that different parameters have opposing effects on the government's optimal currency composition of sovereign debt and inflation decisions.

Figure 9: Cross-Country Variation of LC share w.r.t Each Parameter



Note: The top left panel plots the simulated pairs of LC share and the standard deviation of inflation for the nine countries in the sample, when we *only* use the calibrated income shock process for each country, holding other parameters fixed at the benchmark parameters (Table 2). The top right panel, bottom left panel, bottom right panel, respectively, plot the pairs when we only use the calibrated cost of inflation (ξ), the time discount factor (β), and the output cost of default (λ), holding the other parameters fixed at the benchmark parameters.

Table 7: Comparison of Standard Deviations of Simulated LC Shares.

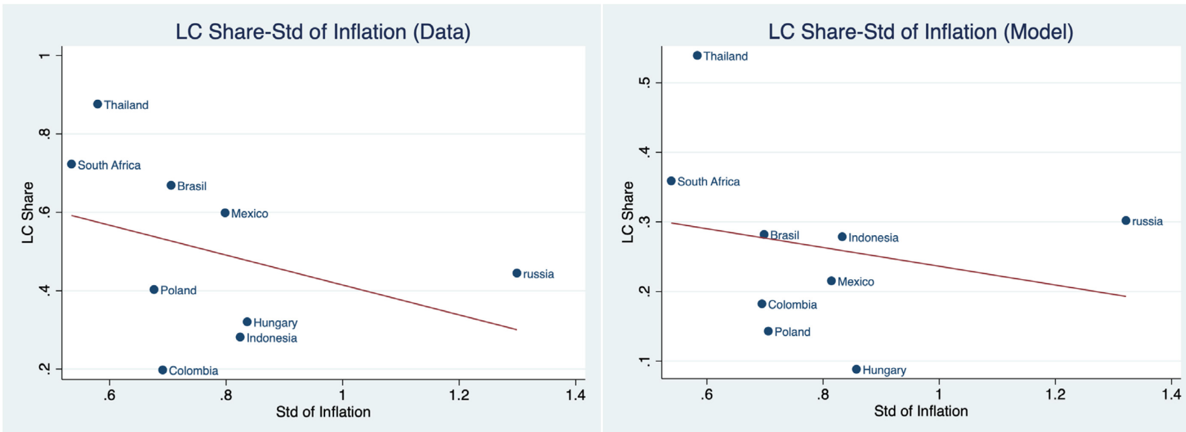
	Benchmark	Income shock Process	Cost of Inflation	Time discount Factor	Output Cost of Default
Std of LC shares	0.132	0.046	0.037	0.081	0.099

To measure each parameter's contribution to the simulated variation of LC share, we compute the standard deviation of LC share for each case. Table 7 reports the standard deviations of simulated LC shares for each simulation exercise. The benchmark denotes the standard deviation of the simulated LC shares for the case in which we allow for the variation of all the parameters for the nine countries as in the top panel of Figure 8. When we only allow for a difference in the income shock processes for those countries, the standard deviation of the LC share is 0.046, which is around 35% of that of the benchmark case (0.132). Note that the sum of the standard deviation for each exercise well exceeds that of the benchmark case because of the opposing effects of variations of different parameters on the LC share.

Table 7 shows that the parameter which generates the highest variation of the LC share is the output cost of default (λ). On the other hand, the parameter which generates the least variation among four parameters is the cost of inflation (ξ). This result shows that contrary to the time variation of LC share, the cross-country variation is mainly accounted for by the cross-country variation of the output cost of default and time discount factor-the empirical counterparts of which are, respectively, the ratio of domestic credit to GDP and the degree of government effectiveness. We can interpret this finding as follows: Once the monetary credibility for the countries which had adopted inflation targeting was established after 2010, the two other factors matter more for the currency composition of the sovereign debt.

This is also consistent with the Figure 7 in the dynamic analysis: we observe in the data that most variation in the ratio of domestic credit to GDP and the degree of government effectiveness are cross-sectional, with not much variation over time.

Figure 10: Comparison of Model and Data (LC share-Std of Inflation)



Why Do We Still Have the Mystery of Original Sin?

Figure 10 plots the pairs of LC share and inflation volatility with a fitted regression line for the data and the model simulation for the nine countries in the sample. We regress the LC share on the standard deviation of inflation for both data and simulated samples. The estimated regression coefficients for both cases are negative, but both are statistically insignificant at the 10% significant level, consistent with the empirical analysis in section 2.1. Using the subset of the data and simulated data, we still have the "mystery of original sin". This weak empirical relationship between a country's inflation performance and local currency borrowing has been considered puzzling, because this fact seems to suggest that debasement risk has little to do with a country's borrowing ability in local currency.

To provide a solution to the "mystery of original sin", we conduct a 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. Appendix C presents a full sensitivity analysis.

The main finding of the sensitivity analysis is that even if the cost of inflation is one of the most important determinants for EM's local currency borrowing, 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, there can be either a positive or negative relationship between these variables. This finding suggests why we still observe the mystery of original sin.

Figure 9 in the cross-country analysis illustrates why we still have a weak empirical relationship between a country's inflation performance and local currency borrowing, even though emerging economies have been able to borrow more in local currency after having adopted inflation targeting in the last decade. Different countries have different characteristics such as different degree of patience, output cost of default, and income volatilities, etc., which determine their borrowing needs and the degree of temptation to breach the contract, as well as the extent to which their governments use inflation to smooth consumption. Different combinations of these characteristics can lead to different pairs of LC share and inflation volatility in equilibrium.

5. 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.

It is well known that there is an inflationary bias when monetary policy is set without commitment.[28] 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 in autarky 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.

5.1. Setup of the Extended Model

Phillips Curve

We use the following Phillips curve:

$$z_t(\pi_t, \pi_e) = \left(1 + \delta(\pi_t - \pi_e)\right) y_t, \tag{36}$$

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 section 3. 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 inflation cost.

When the government does not engage with international lenders through the local currency contract- when the economy is in original sin regime or is in financial autarky- it 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. For this discretionary monetary policy case, we consider a Markov perfect equilibrium. Other than this Phillips curve, all other assumptions in this model are identical to those in the benchmark model in section 3. In Appendix E, we present the full details of the setup of the

[28] See Woodford (2003), chapter 7, for an extensive discussion.

model with the Phillips curve including the values of default, foreign currency borrowing, debasement, and the contract.

5.2. Model Moments

We use the set of parameters from the benchmark calibration as a baseline, but then use different values of δ to see how the slope of the Phillips curve influences economic outcomes. Table 8 compares several simulated 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 Philips 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. The first row in the table 8 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 associated with the high inflation rate. That is, as δ increases, social welfare for the original sin regime, for which the government cannot commit, decreases (the dashed line in Figure 11). 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 excessive 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 and default, so that the debt frontier is enlarged. We can see this in Table 8 from the increase in the maximum local currency borrowing B^l, the LC share of the external debt, the volatility of inflation, and the debt to GDP ratio, as δ increases. With more powerful monetary policy associated with the Philips curve, the social welfare of the economy with the local currency contract increases as δ increases (the blue line in Figure 11).

Table 8: Simulated Moments for the Model with Phillips Curve

	$\delta = 0$ (Benchmark)	$\delta = 0.01$	$\delta = 0.015$	$\delta = 0.02$
Average Inflation Rate for the Original Sin Regime	0%	4.25%	6.43%	8.59%
B^l (% of GDP)	10.5%	11.0%	17.0%	22.0%
Average LC Share (%)	37.47%	46.22%	73.13%	98.02%
$\sigma(\pi_t)$	0.78%	1.52%	1.97%	2.35%
External Debt to GDP ratio	15.68%	17.00%	18.02%	19.59%

5.3. Value of Commitment Device

Figure 11 plots the value of contract $W\left(b_0^{loc}, b_0^{for}, y_0\right)$ and the value of foreign currency borrowing, $W^{for}\left(b_0^{for}, y_0\right)$[29], where $b_0^{loc} = b_0^{for} = 0, y_0 = 1$ for the range of δ from 0 to 0.025. Let U be the difference between $W\left(b_0^{loc}, b_0^{for}, y_0\right)$ and $W^{for}\left(b_0^{for}, y_0\right)$ 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 0.025.

This diagram illustrates how 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[30].

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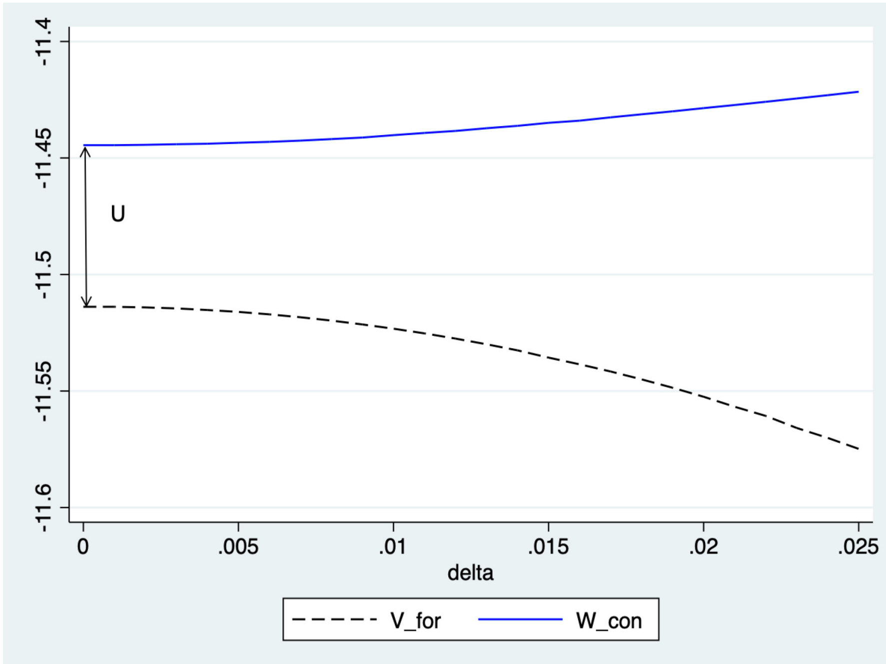
[29] $W^{for}\left(b_0^{for}, y_0\right) = E_0\left[V^{for}\left(b_0^{for}, y_0, y_1\right)\right]$

[30] If the real exchange rate were not constant in our model, a currency depreciation would increase the debt-to-GDP ratio for foreign-currency debt, which would therefore lower the expansionary effect and consumption smoothing

Figure 11: Value of Contract Vs. Value of Foreign Currency Borrowing



6. 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

effect of a depreciation. Such an extension to the model would work to further increase the incentive to maintain credible monetary policy that allows the country to borrow in local currency.

by emerging economies in the recent decades. The cross-country analysis shows why we still have the mystery of original sin. 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 A: Proof of the Propositions

Proposition 1: *Suppose that there is no cost of inflation (i.e., $C(\pi_t - \overline{\pi}) = 0$ for all π_t). Then, the optimal local currency contract under full commitment (i.e., no enforcement constraint eq ((22)) can replicate the consumption allocation under the complete assets market.*

Proof. Suppose that the sovereign in the small open economy can trade a full set of Arrow securities with foreign lenders in the international financial markets. Since foreign lenders in the international financial markets are risk-neutral and the risk-free rate r^* is constant across states and time, the pricing kernel for the Arrow securities is $1/(1+r^*)$ across states and time. Under complete assets market, consumption for the small open economy is equalized across states (i.e., $C_t(s^i) = C_t(s^j)$) at any date *t*, and the following Euler equation characterizes the optimal consumption path over time.

$$\frac{u'(c_t)}{u'(c_{t+1})} = \beta(1+r^*)$$

(Note that the natural borrowing limit is never binding in equilibrium, because the household's utility function satisfies the Inada condition $\lim_{c\to 0} u'(c) = \infty$.)

We first show that the local currency contract under full commitment without any cost of inflation completely smooths consumption across states in equilibrium.

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

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

The Lagrangean for the maximization problem with respect to state-contingent inflation rates is given by

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

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

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

It follows that

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

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

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

Then, we have that $C_t(s^i) = C_t(s^j)$.

The first order condition w.r.t b_{t+1}^{loc} for the maximization problem (eq. (20)) is given by

$$u'(c_t) = \beta(1+r^*)E_t[u'(c_{t+1})]$$

Since consumption across states is equalized, the Euler equation becomes the following:

$$\frac{u'(c_t)}{u'(c_{t+1})} = \beta(1+r^*).$$

Proposition 2: *For sufficiently small values of β, sufficiently low costs of inflation, and sufficiently high output costs of default, there exists no sustainable local currency debt contract in equilibrium, so that the economy must borrow in foreign currency from period 0 onward.*

Proof : We will show that for any small amount of local currency debt $b^{loc} < 0$, if the discount factor β is sufficiently small and the cost of inflation is sufficiently low, then the value of contract is less than the value of debasement for *certain* states of the world, so that there exists *no* sustainable local currency contract supported in equilibrium.

We consider a case in which the output cost of default is sufficiently high so that there exists $b^{for} < 0$ such that the foreign currency borrowing exists for all $y \in Y$ even for $\beta = 0$. Moreover, the value of default is not binding in the enforcement constraint (eq.(26)) for the sufficiently high default cost. $h\left(y_t\right) = 0$ for all $y \in Y$ (that is, the entire income is lost when the economy defaults) is one example.

We first show that with $\beta = 0$ and sufficiently low values of cost of inflation, there is no sustainable local currency contract in equilibrium. Fix a small amount of local currency debt $b_{-1}^{loc} < 0$, and let the amount of foreign currency debt $b_{-1}^{for} = 0$. With $\beta = 0$, the contract attempts to solve the following maximization problem subject to the lender's zero profit condition, *before* y_0 is realized:

$$\underset{i_0, \pi_0(y_0)}{Max} \sum_{y_0} \Pr(y_0 \mid y_{-1})[u(y_0 + \frac{i_0 b_{-1}^{loc}}{\pi_0(y_0)}) - C(\pi_0(y_0) - \overline{\pi})]$$

$$R^* = \sum_{y_0} \Pr(y_0 \mid y_{-1}) \frac{i_0}{\pi_0(y_0)}$$

Let λ be the Lagrange multiplier associated with the zero-profit condition. Then the first order condition w.r.t $\pi_0(y_0(s))$ is given by

$$[u'(c_o(y_0(s))(-\frac{i_0 b_{-1}^{loc}}{\pi_0^2(s)}) - C'(\pi_0(s))] = \lambda \frac{i_0}{\pi_0^2(s)} \text{ for all } y_0(s) \in Y .$$

After y_0 is realized, however, the government finds it optimal to breach the contract through excessive debasement at all states of the world if the cost of inflation is sufficiently low and the cost of default is sufficiently high.

The first order condition w.r.t. $\pi_0(y_0(s))$ for the value of debasement after $y_0(s)$ is realized is given by

$$[u'(c_o(y_0(s))(-\frac{i_0 b_{-1}^{loc}}{\pi_0^2(s)}) - C'(\pi_0(s))] = 0 \text{ for all } y_0(s) \in Y .$$

Since λ and i_0 are positive, the contract cannot replicate the value of debasement at each state. When $\beta = 0$ and the cost of inflation is sufficiently low, no sustainable local currency debt can be constructed: Households do not put any value on the future continuation value following the contract, and the gain from a consumption increase through ex-post excessive debasement is high. Note that with a sufficiently high cost of inflation, we have a corner solution at $\pi_0(s) = \overline{\pi}$ for all s for the cases of the contract and debasement; thus a sustainable local currency debt exists in equilibrium even with $\beta = 0$.

Now consider the case in which β lies between 0 and 1. Fix a small amount of $b^{loc} < 0$, and $y, y' \in Y$. Let $V^{c,no}(0, b^{loc}, y, y')$ be the value of the optimal contract *under full commitment (i.e., no enforcement constraint eq (*(26)*)* with $b^{for} = 0$, b^{loc}, y, and y'. Note that if there exists no sustainable local currency contract with $b^{for} = 0$, there exists no sustainable local currency contract with $b^{for} < 0$. This is because the incentive for excessive debasement is higher for the case with a positive amount of foreign currency debt.

Let $f\left(\beta;b^{loc},y,y'\right)\equiv\left\{V^{c,no}\left(0,b^{loc},y,y';\beta\right)-V^{debase}\left(0,b^{loc},y,y';\beta\right)\right\}$. If $f\left(\beta;b^{loc},y,y'\right)<0$, there exists no sustainable local currency contract that can support $b^{loc}<0$ with $y,\ y'$ and β. We have already shown $f\left(\beta=0;b^{loc},y,y'\right)<0$ for a sufficiently low cost of inflation.

Let β^H be the time discount factor very close to but less than one. Then we have either of the following two cases at β^H.

Case (1): $f\left(\beta^H;b^{loc},y,y'\right)>0$. Since $f(.)$ is continuous in β, it follows from the intermediate value theorem that there exists $0<\beta'<\beta^H$ such that $f\left(\beta';b^{loc},y,y'\right)=0$. At this point, $\left(\beta',b^{loc},y,y'\right)$, we have:

$$u(c_t^{c,no})-C(\pi_t^{c,no})+\beta W^{c,no}(b_{t+1}^{c,for},b_{t+1}^{c,loc},y')=u(c_t^{debase})-C(\pi_t^{debase})+\beta E_t V^o(b_{t+1}^{debase,for},y''),\qquad (1)$$

where the left hand side is $V^{c,no}\left(0,b^{loc},y,y';\beta\right)$, and the right hand side $V^{debase}\left(0,b^{loc},y,y';\beta\right)$.

It follows from the Envelope conditions for the values of contract and debasement w.r.t β that

$$f_\beta\left(\beta';b^{loc},y,y'\right)=V_\beta^{c,no}-V_\beta^{debase}=W^{c,no}-E_tV^{for}.$$

Since $\left[u\left(c_t^{debase}\right)-C\left(\pi_t^{debase}\right)\right]-\left[u\left(c_t^{c,no}\right)-C\left(\pi_t^{c,no}\right)\right]>0$, we have that $W^{c,no}-E_tV^{for}>0$ from eq (1), thus $f_\beta\left(\beta';b^{loc},y,y'\right)>0$ at this point. That is, at β' for which the values of contract and debasement are equalized, an increase in β at β' increases $V^{c,no}$ more than V^{debase}. This implies that $f\left(\beta;b^{loc},y,y'\right)$ crosses the β axis only once. Hence, there exists β' such that for any $0<\beta<\beta'$, $f\left(\beta;b^{loc},y,y'\right)<0$. Since the value of contract with the enforcement constraint V^c is less than or equal to the value of contract without the enforcement constraint $V^{c,no}$, there exists a small value of β for which there exists *no* sustainable local currency contract, so that the economy must borrow *only* in foreign currency from period 0 onward.

Case (2): $f\left(\beta^H;b^{loc},y,y'\right)\le 0$. In this case, we cannot use the intermediate value theorem. However, suppose that there exists $0<\beta^*<\beta^H$ such that $f\left(\beta^*;b^{loc},y,y'\right)=0$. As shown in the case (1), at the point for which $f\left(\beta^*;b^{loc},y,y'\right)=0$, we have that $f_\beta\left(\beta^*;b^{loc},y,y'\right)>0$. This single crossing property implies that if $f\left(\beta=0;b^{loc},y,y'\right)<0$ and $f\left(\beta^{H};b^{loc},y,y'\right)\leq 0$, there exists no $0<\beta^{*}<\beta^{H}$ such that $f\left(\beta^{*};b^{loc},y,y'\right)=0$. In this case, the value of debasement is strictly larger than the value of contract all over $\beta's$, thus no local currency borrowing all over the range.

Proposition 3: *If* $C\left(\pi_t-\overline{\pi}\right)=\infty$ *for any* $\pi_t\neq\overline{\pi}$*,* then $\pi_t\left(s^t\right)=\overline{\pi}$ 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 $\overline{\pi}$ incurs an infinitely high cost of inflation, we have that $\pi_t\left(s^t\right)=\overline{\pi}$ in equilibrium. With the equilibrium inflation being $\overline{\pi}$ at any state of the world, the nominal interest rate on local currency debt i_{t+1} becomes $\overline{\pi}R^{*}$ 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.

Appendix B: Calibrated Parameters and Moments for Cross-Country Analysis

In this section we present calibrated parameters and empirical and simulated moments for the nine countries for the cross-country analysis in Section 4.

1. Brazil

Target Moments	Empirical Moments	Simulated Moments	Parameters	Estimated Values
Std of Inflation Rate (%)	0.70	0.69	ξ	0.119
$Corr(\Delta Y_t, \pi_t)$	-0.57	-0.65	β	0.964
External Government Debt (% of GDP)	7.41	7.19	λ	0.0025
Non-Target Moments			ρ_e	0.72
LC Share	0.66	0.28	σ_e	0.0180

2. Colombia

Target Moments	Empirical Moments	Simulated Moments	Parameters	Estimated Values
Std of Inflation Rate (%)	0.69	0.69	ξ	0.124833
$Corr(\Delta Y_t, \pi_t)$	-0.58	-0.66	β	0.974635
External Government Debt (% of GDP)	18.64	19.13	λ	0.006887
Non-Target Moments			ρ_e	0.7895
LC Share	0.19	0.18	σ_e	0.0180

3. Hungary

Target Moments	Empirical Moments	Simulated Moments	Parameters	Estimated Values
Std of Inflation Rate (%)	0.83	0.85	ξ	0.071747
$Corr(\Delta Y_t, \pi_t)$	-0.66	-0.53	β	0.978062
External Government Debt (% of GDP)	25.90	25.69	λ	0.009
Non-Target Moments			ρ_e	0.6654
LC Share	0.32	0.088	σ_e	0.0182

4. Indonesia

Target Moments	Empirical Moments	Simulated Moments	Parameters	Estimated Values
Std of Inflation Rate (%)	0.82	0.83	ξ	0.123
$Corr(\Delta Y_t, \pi_t)$	-0.59	-0.70	β	0.975
External Government Debt (% of GDP)	16.78	16.55	λ	0.0061
Non-Target Moments			ρ_e	0.7869
LC Share	0.28	0.27	σ_e	0.0180

5. Mexico

Target Moments	Empirical Moments	Simulated Moments	Parameters	Estimated Values
Std of Inflation Rate (%)	0.79	0.81	ξ	0.11
$Corr(\Delta Y_t, \pi_t)$	-0.54	-0.68	β	0.976
External Government Debt (% of GDP)	19.97	19.01	λ	0.0069
Non-Target Moments			ρ_e	0.7580
LC Share	0.598	0.215	σ_e	0.0180

6. Poland

Target Moments	Empirical Moments	Simulated Moments	Parameters	Estimated Values
Std of Inflation Rate (%)	0.67	0.70	ξ	0.099
$Corr(\Delta Y_t, \pi_t)$	-0.49	-0.67	β	0.976
External Government Debt (% of GDP)	20.50	20.83	λ	0.0073
Non-Target Moments			ρ_e	0.6494
LC Share	0.403	0.143	σ_e	0.0183

7. Russia

Target Moments	Empirical Moments	Simulated Moments	Parameters	Estimated Values
Std of Inflation Rate (%)	1.29	1.32	ξ	0.059
$Corr(\Delta Y_t, \pi_t)$	-0.61	-0.71	β	0.974
External Government Debt (% of GDP)	11.80	11.54	λ	0.0045
Non-Target Moments			ρ_e	0.8349
LC Share	0.445	0.301	σ_e	0.0181

8. South Africa

Target Moments	Empirical Moments	Simulated Moments	Parameters	Estimated Values
Std of Inflation Rate (%)	0.53	0.53	ξ	0.250138
$Corr(\Delta Y_t, \pi_t)$	-0.47	-0.69	β	0.975675
External Government Debt (% of GDP)	16.55	16.00	λ	0.006096
Non-Target Moments			ρ_e	0.8137
LC Share	0.723	0.359	σ_e	0.0180

9. Thailand

Target Moments	Empirical Moments	Simulated Moments	Parameters	Estimated Values
Std of Inflation Rate (%)	0.57	0.58	ξ	0.58347
$Corr(\Delta Y_t, \pi_t)$	-0.049	-0.66	β	-0.6679
External Government Debt (% of GDP)	61.225	61.38	λ	0.06138
Non-Target Moments			ρ_e	0.6403
LC Share	0.876	0.539	σ_e	0.0183

Appendix C: Identification and Sensitivity Analysis

In this section, we first elaborate on the identification of the calibrated parameters (β, ξ, λ) and then conduct a sensitivity analysis with respect to several key parameters to investigate the effects of changes in these key parameters on the optimal composition of sovereign debt.

Identification

All three calibrated parameters (β, ξ, λ) affect the three target moments in our model. Since it is straightforward that the two target moments-the standard deviation of inflation rate and the debt to GDP ratio- are affected by the three parameters, we only explain in this subsection how each parameter affects the correlation between ΔY_t and π_t. The main point is that when a sovereign can borrow more in local currency, it conducts more active monetary policy, so that the correlation between ΔY_t and π_t gets more negative to take advantage of consumption smoothing function of the local currency debt. (See Corollary 1).

After that, using the argument from Andrews, Gentzkow, and Shapiro (QJE, 2017)[31], we show how the three parameters are separately identified from the simulated moments.

We first show how each parameter affects the correlation between ΔY_t and π_t based on Table 4 in our paper, in which we compare simulated moments across different parameter values.

1) The increase in ξ allows the sovereign to borrow more in local currency. The sovereign conducts more active monetary policy to take advantage of consumption smoothing function of local currency debt. Hence, we see a more negative correlation between ΔY_t and π_t after the increase.

2) The increase in β leads to an increase in the sovereign's commitment to the local currency debt, so that the sovereign can borrow more in local currency. Hence we see a more negative correlation.

3) The increase in the output cost of default (λ) leads to a decrease in the local currency borrowing, as it relaxes the foreign currency borrowing limit more than the local currency borrowing limit. Hence, this makes the correlation less negative.

We now show how all three parameters are separately identified from the data moments based on table 4. First note (1) that a decrease in ξ, holding the other two parameters at the calibrated values, leads to an increase in the standard deviation of inflation in simulation. (2) that an increase in β leads to an increase in the standard deviation of inflation, (3) that an increase in λ leads to an increase in the standard deviation

[31] " Measuring the Sensitivity of Parameter Estimates to Estimation Moments", Andrews, Gentzkow, and Shapiro, Nov.2017, Quarterly Journal of Economics.

of inflation. That is, a lower cost of inflation, a higher time discount factor, and a higher cost of default imply the same qualitative change in the standard deviation of inflation.

1. However, ξ and β are separately identified because they have different quantitative implications for the mean debt to GDP ratio. The decrease in ξ leads to almost no change in the mean debt to GDP ratio, whereas the increase in β leads to a decrease in the debt to GDP ratio.

2. β and the output cost of default λ are separately identified from the data, because they have different qualitative implications for the two other moments. The increase in β leads to a decrease in the correlation between ΔY_t and π_t and the debt to GDP ratio, whereas the increase in λ leads to an increase in the correlation and the debt to GDP ratio.

Discount Factor

Figure C-1: Sensitivity Analysis w.r.t Time Discount Factor

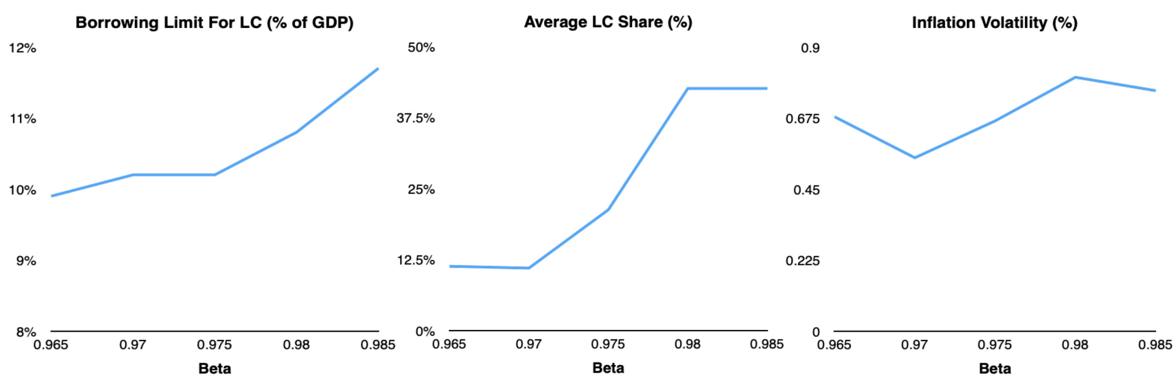


Figure C-1 shows sensitivity analysis with respect to the discount factor β ranging from 0.965 to 0.985. As a sovereign becomes more patient, it becomes less tempted to excessive debasement or default on debt. Accordingly, the economy can and does borrow more in local currency. As the economy borrows more in local currency, the sovereign more actively conducts monetary policy to take advantage of the hedging benefit of local currency debt.

Degree of Risk Aversion

Figure C-2: Sensitivity Analysis w.r.t Degree of Risk Aversion

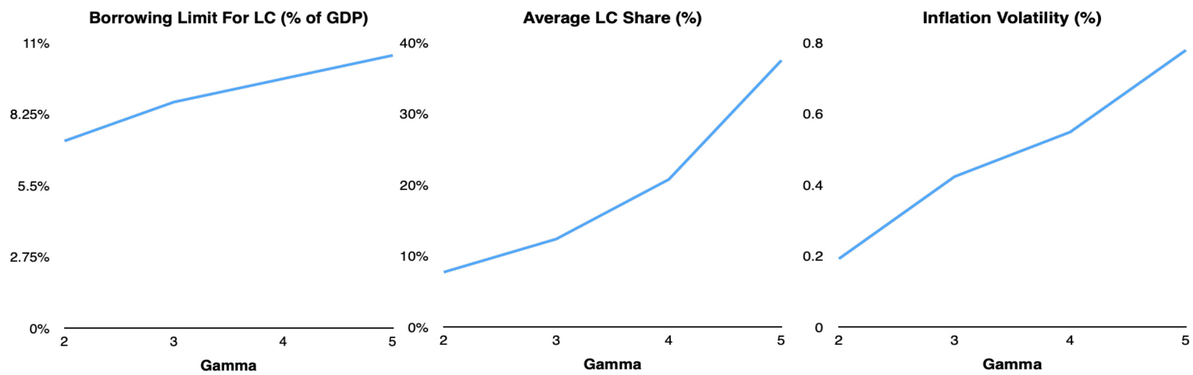


Figure C-2 displays sensitivity analysis with respect to different values of γ. As households become more risk averse, they value consumption smoothing more, and thus prefer to borrow in local currency. Hence, the maximum borrowing limit for the local currency debt B^l increases with the degree of risk aversion. Even though the local currency share of debt increases, inflation volatility increases. 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 hedging benefit of local currency debt.

Output Cost of Default

Figure C-3: Sensitivity Analysis w.r.t Output Cost of Default

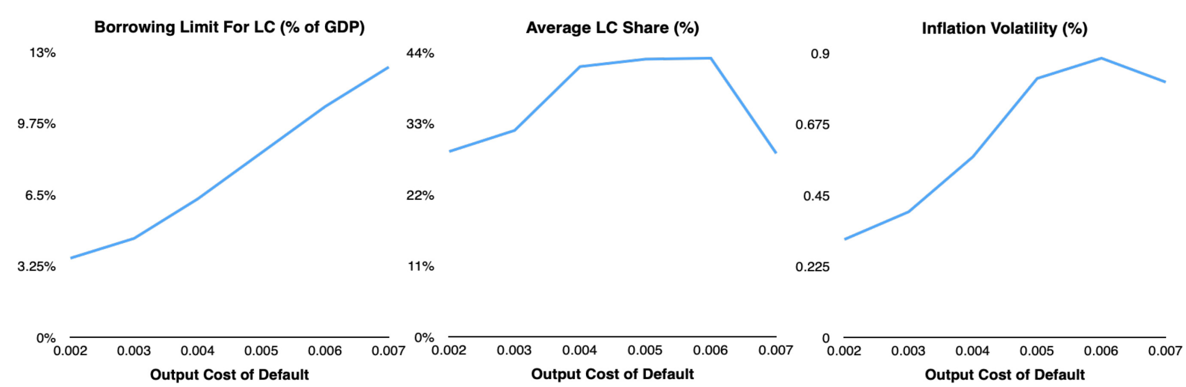


Figure C-3 shows sensitivity analysis with respect to different output cost parameters λ. As the output cost of default increases, the borrowing limit for local currency increases, so the economy can borrow more in local currency. However, the average local currency share shows a hump shape with λ. We have two opposing effects on the LC share along with the increase in λ. First, as the borrowing limit for LC increases, the economy can borrow more in local currency. Second, compared to the local currency debt, the borrowing limit for foreign currency debt gets more relaxed with λ as shown in Figure 5. The economy then tends to borrow relatively more in foreign currency than in local currency. Depending on the relative sizes of these two effects, the average LC share can increase or decrease. Note that this non-linearity in the movement of the LC share is more pronounced with the equilibrium default and temporary financial autarky. It is because in the current setup, the value of default directly affects the value of debasement.

Income Variance

Figure C-4: Sensitivity Analysis w.r.t Income Variance

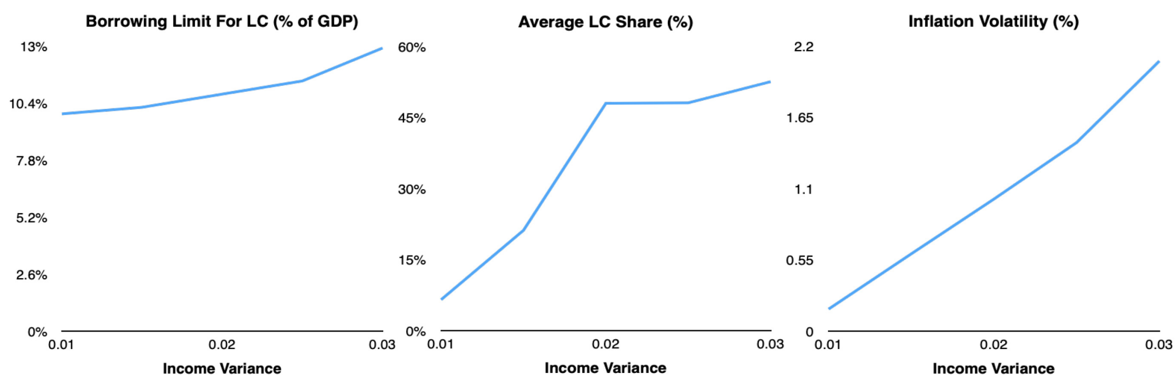


Figure C-4 presents sensitivity analysis with respect to different levels of income variance. As the variance of income increases, the value of breaching the contract decreases; the values of debasement and default decrease, because the economy has a less efficient consumption smoothing vehicle in the original sin regime and permanent financial autarky in the face of higher income volatility. As the variance of income increases, the borrowing limit for local currency debt increases. Along the way, both the LC share and inflation volatility increase.

Persistence of Income Shock

Figure C-5: Sensitivity Analysis w.r.t Persistence of Income Shock

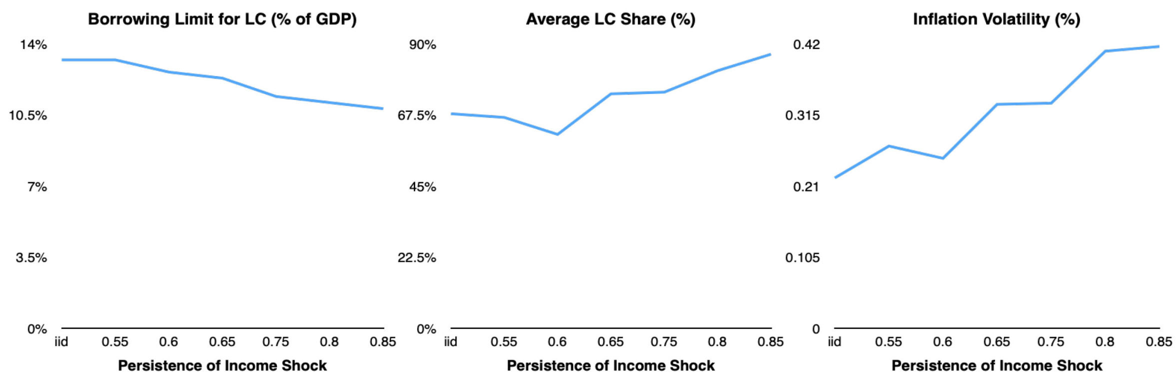


Figure C-5 presents sensitivity analysis with respect to different degrees of persistence of the income shock process. As the income shock becomes more persistent, the value of debasement/default increases; when a good income shock hits the economy, the good income shock is expected to persist for a 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, as with the sensitivity analysis w.r.t output cost of default, the degree of persistence in the income process affects the relative tightness of the local and foreign currency debt limit through the changes in the values of default and debasement. Hence, the average LC share and inflation volatility shows a non-linear shape.

Appendix D: Robustness Check and Counterfactual Analysis with Equal Punishment

In the section, we consider the robustness of our findings to alternative model set-ups.

In Appendix D-1, rather than staying in the original sin regime permanently after excessive debasement, in each period the model economy has a recurring chance to escape from the original sin regime with an exogenous probability. In Appendix D-2, we compare the simulated results for different lengths of the financial autarky punishment for default. The chief takeaway from this exercise is that the different specifications of the punishment for default and/or debasement mainly affect the enforcement constraint (eq. (22)) through changes in the values of default and/or debasement, but this change does not lead to any major change to our main quantitative results. In the Appendix D-3, we conduct an analysis in which financial autarky is imposed on the economy whether it breaches the contract with outright default or excessive debasement.

D-1 Model with Temporary Original Sin Regime

Figure D-1

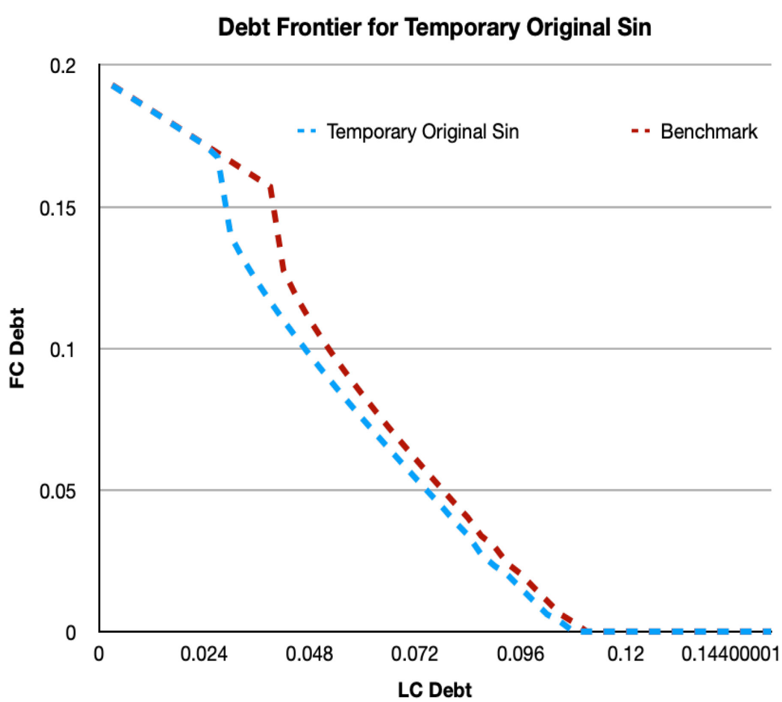


Figure D-1 compares the debt frontiers for the benchmark model and the model with the temporary original sin regime. We set the exogenous probability of escaping from the original sin regime to be 1/40 , the same as that of re-entering the credit market from financial autarky. The recurring chance of escaping from the original sin regime increases the value of foreign currency, thus increasing the value of debasement. The tighter debt frontier along the local currency borrowing for the model with temporary original sin regime shows this point. Table D-1 compares the simulated moments for the benchmark calibration and the model with the temporary original sin regime. Since the debt frontier for the model with temporary original sin regime is tighter along the local currency borrowing, the model economy cannot borrow in local currency as much as in the benchmark model. Hence, its mean LC debt and LC share are smaller than those for the benchmark model. Other than that, the two simulated moments are similar both qualitatively and quantitatively.

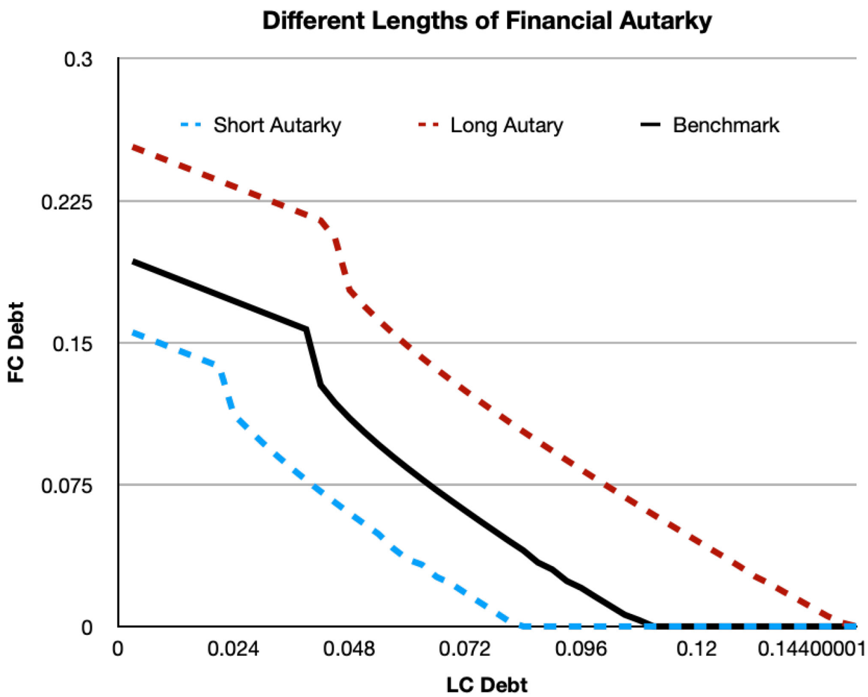
Table D-1: Comparison of Simulated Moments

Description	Temporary Original Sin	Benchmark
B^l **(% of GDP)**	10.2%	10.50%
Mean LC Share (%)	0.2899	0.3747
Mean Total Debt (% of GDP)	15.62%	15.68%
$corr(Y, LC\ share)$	0.6531	0.6323
$corr(\Delta Y, \pi)$	-0.6610	-0.8111
$corr(\Delta C, \pi)$	-0.5062	-0.7015
$corr(TB/Y, Y)$	0.6578	0.6598
$corr(\pi_{t-1}, \pi_t)$	0.0011	-0.0015
$\sigma(\pi_t)$ **(%)**	0.65%	0.78%
$\sigma(TB/Y)$ **(%)**	1.05%	1.05%

D-2 Different Lengths of Financial Autarky

In this section, we compare the simulated moments for the cases with different lengths of financial autarky. The exogenous probability of escaping from financial autarky to the credit markets in the benchmark calibration and cross-country analysis θ is set to be 1/40 (i.e., the expected financial autarky is 10 years.). Figure D-2 shows the debt frontiers for the cases of short and long financial autarky (θ=1/30 and θ=1/60)

Figure D-2



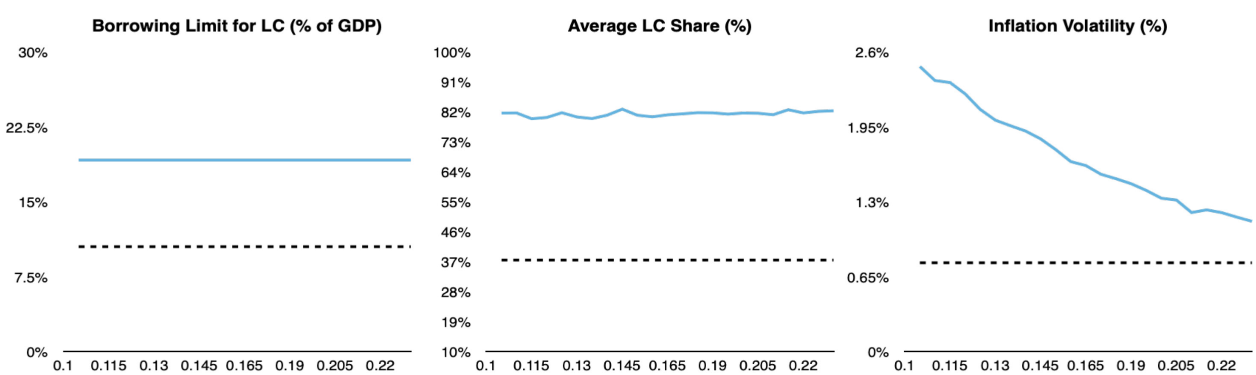
The probability of re-entering the credit market affects both the value of debasement through the value of foreign currency borrowing and the value of default V_{loc}^{def} . For the case of short financial autarky as a punishment, the values of debasement and default are higher than those for the benchmark case, so that the debt frontier shrinks overall. On the other hand, for the case of long financial autarky, the debt frontier enlarges. Table D-2 compares the simulated moments for the benchmark calibration, and the cases of short and long financial autarky. As with changes in the output cost of default (the last two columns of Table 4) in section 4, the increase in the length of financial autarky relaxes foreign currency borrowing more than local currency borrowing, so that for the case of long financial autarky, the economy borrows more in local currency in absolute amount, but its LC share is slightly lower than that for the case of short financial autarky. Other than that, the three simulated moments are similar both qualitatively and quantitatively.

Table D-2: Comparison of Simulated Moments

Description	Short Financial Autarky	Long Financial Autarky	Benchmark
B^l **(% of GDP)**	7.8%	14.70%	10.50%
Mean LC Share (%)	0.3156	0.3011	0.3747
Mean Total Debt (% of GDP)	11.88%	21.67%	15.68%
$corr(Y, LC\ share)$	0.6562	0.5548	0.6323
$corr(\Delta Y, \pi)$	-0.6453	-0.6632	-0.8111
$corr(\Delta C, \pi)$	-0.4976	-0.5070	-0.7015
$corr(TB / Y, Y)$	0.6576	0.6628	0.6598
$corr(\pi_{t-1}, \pi_t)$	-0.005	-0.004	-0.0015
$\sigma(\pi_t)$ **(%)**	0.55%	0.88%	0.78%
$\sigma(TB / Y)$ **(%)**	1.05%	1.06%	1.05%

Appendix D-3: Counterfactual Analysis: the Case with No Debasement Risk

Figure D-3 : Sensitivity Analysis w.r.t Cost of Inflation (ξ) with Equal Punishment



The x-axis is the cost of inflation parameter (ξ) and ranges from 0.1 to 0.225. The dashed line denotes the value from the benchmark calibration.

The corollary to proposition 2 shows that if excessive currency debasement is punished with financial autarky as with outright default, the sovereign can always borrow in local currency because local currency debt has no debasement risk. In this section, we analyze the implications of the equal punishment of financial autarky, whether because of breaches to the contract with excessive debasement or outright default. We only vary the cost of inflation parameter, fixing all other parameter values at those from the benchmark calibration, so that we can make a comparison with the sensitivity analysis with debasement risk in Figure 6.

Figure D-3 plots the maximum local currency borrowing limits B^l, average local currency shares of sovereign debt, and inflation volatilities from the simulated models for different values of the cost of inflation parameter ξ under equal punishment. The black dashed line denotes the value from the benchmark calibration[32] (Table 3 in the main text). With no debasement risk, the maximum borrowing limit for local currency (19.16% of GDP) is much more relaxed than that from the benchmark calibration (10.50%). Moreover, it stays constant across the cost of inflation.[33] The average LC share is much higher than that from the benchamark calibration, and it is stable at around 82%. This pattern is contrasted with that from the sensitivity analysis with debasement risk (Figure 6). Moreover, inflation volatility is much higher than the benchmark one, because monetary policy is much less constrained with no debasement risk. As with the sensitivity analysis in Figure 6, however, the inflation volatility decreases with the cost of inflation.

This analysis shows that the debasement risk associated with local currency debt is a key factor in determining EM economies' ability to borrowing in local currency, and it provides additional support for the assumption of different punishments in our model.

Appendix E: Model with Phillips Curve

In this section, we present the full details of the setup of the model extended to include the Phillips curve.

Phillips Curve

We use the following Phillips curve:

$$z_t\left(\pi_t, \pi_e\right) = \left(1 + \delta\left(\pi_t - \pi_e\right)\right) y_t, \tag{2}$$

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 section 3. 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 inflation cost.

[32] The benchmark cost of inflation parameter ξ is calibrated at 0.117.

[33] As the cost of inflation increases, the value of local currency contract decreases as monetary policy is more costly, but the value of default also decreases as it contains the value of contract. The economy in autarky can regain access to the local currency borrowing with the probability of θ. We find that for a range of higher costs of inflation, the borrowing limit for LC decreases with the cost of inflation.

When the government does not engage with international lenders through the local currency contract- when the economy is in original sin regime or is in financial autarky- it 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. For this discretionary monetary policy case, we consider a Markov perfect equilibrium. Other than this Phillips curve, all other assumptions in this model are identical to those in the benchmark model in section 3.

Value of Default

The value of default, when the economy enters financial autarky from the foreign currency borrowing regime, is given by

$$V_{for}^{def}\left(y_{t-1}, y_t; \pi_e\right) = \max_{\pi_t}\left[u\left(c_t\right) - C\left(\pi_t - \overline{\pi}\right)\right] + \beta(1-\theta)E_t\left[V_{for}^{def}\left(0, y_t, y_{t+1}; \pi_e^{'}\right)\right] + \beta\theta E_t[V^o(0, y_t, y_{t+1}; \pi_e^{'})] \tag{3}$$

Likewise, the value of default, when the economy enters financial autarky from the local currency borrowing regime, is given by

$$V_{loc}^{def}\left(y_{t-1}, y_t; \pi_e\right) = \max_{\pi_t}\left[u\left(c_t\right) - C\left(\pi_t - \overline{\pi}\right)\right] + \beta(1-\theta)E_t\left[V_{loc}^{def}\left(0, y_t, y_{t+1}; \pi_e^{'}\right)\right] + \beta\theta W(0, 0, y_t), \tag{4}$$

Both value functions are subject to

$$c_t = h\left(z_t\left(\pi_e, \pi_t\right)\right). \tag{5}$$

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. With the assumption that π_t is Markovian, π_e, the rational expectations of π_t [34] is formed before y_t is realized, and is given by:

$$\pi_e = E_{t-1}\left[\pi_t\right] \tag{6}$$

Note that because of the above equation determining the rationally expected inflation π_e, the value of default contains y_{t-1} as a state variable.

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[34] With the chance of re-entering credit markets θ,
$\pi_e^{def,loc} = E_{t-1}\left[\pi_t\right] = \left(1-\theta\right)E_{t-1}\left[\pi_t^{def,loc}\left(y_{t-1}, y_t\right)\right] + \theta E_{t-1}\left[\pi_t^c\left(0, 0, y_{t-1}, y_t\right)\right]$ and
$\pi_e^{def,for} = \left(1-\theta\right)E_{t-1}\left[\pi_t^{def,for}\left(y_{t-1}, y_t\right)\right] + \theta E_{t-1}\left[\pi_t^{for}\left(0, y_{t-1}, y_t\right)\right]$ where the superscripts denote the economy's current regime.

Value of Foreign Currency Borrowing (Original Sin Regime)

The value of foreign currency borrowing is given by

$$V^{for}\left(b_t^{for}, y_{t-1}, y_t; \pi_e\right) = \max_{\pi_t, b_{t+1}^{for}} \left[u\left(c_t\right) - C\left(\pi_t - \bar{\pi}\right)\right] + \beta E_t\left[V^o\left(b_{t+1}^{for}, y_t, y_{t+1}; \pi_e'\right)\right] \qquad (7)$$

subject to

$$c_t + q(b_{t+1}, y_t) b_{t+1}^{for} = z_t\left(\pi_t, \pi_e\right) + b_t^{for} \qquad (8)$$

$$b_{t+1}^{for} \geq -D \qquad (9)$$

Finally, when solving the above problem, the government takes π_e as given, and π_e [35] is determined by the following equation:

$$\pi_e = E_{t-1}[\pi_t] \qquad (10)$$

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 $z_t\left(\pi_t, \pi_e\right)$ 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 also 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 agreed

[35] $\pi_e^{for} = \Pr\left(default\right) E_{t-1}\left[\pi_t^{def,for}\left(y_{t-1}, y_t\right)\right] + \left(1 - \Pr\left(default\right)\right) E_{t-1}\left[\pi_t^{for}\left(b_t, y_{t-1}, y_t\right)\right]$, and the probability of default is endogenously determined by the values of default and foreign currency borrowing.

upon with the foreign lenders, even though it is constrained to a certain extent. Hence, foreign lenders in this case double as a commitment device which can punish the government for the deviation from the monetary policy specified in the contract. That is, by agreeing to 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.

Appendix F: Computation Algorithm

In this section we describe the computation algorithm to solve the recursive problem (eq.(24) - eq.(27)). As pointed out by Chang (1998), and Bai and Zhang (2010), the unique feature of this algorithm is that we need to find a set of states $S = (b^{for}, b^{loc}, y)$ that permit a non-empty set of feasible allocation on the value function $W(b^{for}, b^{loc}, y)$, which is used to construct the debt frontier of our model. We need to start with a sufficiently high W^0, where superscript denotes the number of iterations. We first solve the recursive problem without the enforcement constraints to obtain the value W^0, which is used for our initial guess for *W*. For each iteration *i*, we solve the recursive problem to update S^i to include all the states (b^{for}, b^{loc}, y) which satisfy the budget and the enforcement constraints. As shown by Bai and Zhang (2010), both sequence of $\{W^i, S^i\}$ are decreasing and finally converging to the limit W, S.

We solve for equilibrium using the global solution method featuring the value function iteration. We first generate a discrete grid for (b^{for}, b^{loc}, y). Given $\{W^i, S^i\}$ at the *i*th iteration, we solve for the optimal inflation rate, the optimal i_t, and the optimal amount of local and foreign currency debts $(\pi_t, b_{t+1}^{for}, b_{t+1}^{loc})$ subject to the enforcement constraint. When computing the optimal $(\pi_t(y_t(s)), i_t)$, we use the Nelder-Mead algorithm subject to lender's zero profit condition and the optimality condition for the interest rate (eq (27)). We keep iterating the value functions and S^i until achieving convergence with a convergence criterion of 10^{-6} sup norm.

Finally, the income shock process y_t is approximated with the two state Markov Chain using the method by Kopecky and Suen (2010).