Sovereign Debt Portfolios, Bond Risks, and the Credibility of Monetary Policy

Wenxin Du, Carolin E. Pflueger, and Jesse Schreger[1]

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[1]Du: Federal Reserve Board, 20th and C Street NW, Washington, D.C. 20551. Email wenxin.du@frb.gov. Pflueger: University of British Columbia, Vancouver BC V6T 1Z2, Canada. Email carolin.pflueger@sauder.ubc.ca. Schreger: Princeton University and Harvard Business School, Fisher Hall, Princeton, NJ 08540. Email: schreger@princeton.edu.

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Abstract

We document large cross-country variations in the cyclicality of nominal bond returns across 30 developed and emerging markets over the past decade. We show that countries with more procyclical nominal bond returns rely less on nominal debt in their sovereign debt portfolios, despite of the better hedging property of the nominal debt from the issuer's perspective. We explain these findings using a tractable model featuring imperfect monetary policy credibility and an endogenous currency composition of sovereign debt. A low credibility government issues foreign currency debt to constrain next period's incentive to inflate away the debt. Cost-push shocks to a New-Keynesian Phillips curve create high inflation during recessions and positive local currency bond betas. In contrast, a high credibility government issues local currency debt and offsets recessionary cost-push shocks by strengthening its commitment to low future inflation, thereby raising local currency bond returns in recessions.

1 Introduction

Over the past decade, the market for emerging market government debt has undergone a remarkable transformation. In the 1980s and 1990s, most emerging market sovereigns and several developed country governments relied heavily on foreign currency (FC) in their foreign borrowing. This left the borrowers vulnerable to currency fluctuations and financial crises (Eichengreen and Hausmann 1999). Since the Asian Financial Crisis, the share of government bonds issued in local currencies (LC) has grown rapidly, constituting more than half of external debt issued by major emerging market sovereigns (Du and Schreger 2015b). However, the shift towards local currency government bonds has been highly uneven across markets, raising the question of what drives these differences. In this paper, we show that despite of the better hedging property of nominal debt from the issuer's perspective, countries with more procyclical nominal bond risk have lower shares of nominal debt in their sovereign debt portfolios. This empirical finding is at odds with a standard portfolio choice model with an exogenous inflation process but we show it can be explained by a model of endogenous sovereign debt denomination and monetary policy under imperfect monetary policy credibility.

We begin by documenting the significant cross-country heterogeneity in the cyclicality of nominal bond risk. Using a sample of 30 developed and emerging markets with sizable nominal local currency bond markets, we find that over the last decade the nominal bond-stock betas vary substantially across countries, ranging from negative 0.2 to positive 0.3. In particular, in developed markets, nominal bond returns are counter-cyclical (i.e., negative bond-stock betas). In emerging markets, nominal bond returns are generally pro-cyclical (i.e., positive bond-stock betas). In addition to measuring nominal bond excess returns with respect to stock market movements, we also obtain a similar cross-sectional pattern of nominal bond returns with respect to sovereign default risk variations, as measured by changes in sovereign credit default swaps (CDS) spreads. Positive bond-stock betas coincide with negative bond-CDS betas. In countries with positive (negative) bond-stock betas, bond excess returns are higher during good (bad) times when the CDS spreads are lower (higher). Furthermore, the cyclicality of bond returns covaries strongly with expected inflation cyclicality, as would be expected if inflation expectations are a key driver of nominal bond returns. Using inflation and output forecasting data from Consensus Economics, we measure the expected inflation cyclicality as the regression coefficient in a regression of revisions to inflation forecasts on revisions to output forecasts. We show that these inflation forecast betas are highly correlated with nominal bond betas across countries. Taken together, this evidence on the cyclicality of nominal bond returns is our way of measuring whether nominal debt is a good or bad hedge for domestic macroeconomic activity.

The second set of stylized facts we document are about the strong empirical relationship between the cyclicality of nominal risk and the share of nominal debt in sovereign debt portfolios. In particular, countries with more pro-cyclical nominal bond returns (higher bond-stock betas and lower bond-CDS betas) and less pro-cyclical expected inflation (lower inflation forecast betas) generally rely less on nominal debt relative to real or foreign currency debt. This empirical relationship is at first puzzling as it means that the countries that should have the most to gain from borrowing in their own currency do so the least. From the sovereign issuer's perspective, one main advantage of nominal debt over real debt (or foreign currency debt) is that it allows the sovereign to smooth real debt repayments across states via inflation. In countries with more procyclical bond returns or more counter-cyclical inflation, nominal debt should be particularly attractive to the issuer as the real debt repayment is low in the bad states of the world.

Based on these empirical findings, we develop an analytically tractable model of the government's optimal portfolio of liabilities and monetary policy, building on a standard log-linearized New Keynesian framework. The central bank can engage in forward guidance and communicate a contingent plan for future monetary policy, but a low credibility central bank is likely to act myopically (Kydland and Prescott 1977, Barro and Gordon 1983, Rogoff 1985) and may inflate away local currency debt. In the model, the degree of monetary policy credibility drives the optimal portfolio of government liabilities and the level and cyclicality of inflation and default risk, and thereby creating the negative relationship between bond-stock betas and the share of nominal debt in sovereign debt portfolios. We keep the model tractable by assuming that local currency bonds and stocks are priced by a risk-neutral international investor and purchasing power parity.

Monetary policy credibility matters for the government's trade-off between issuing local currency (LC) and foreign currency (FC) debt, because low credibility and local currency debt interact and generate an incentive to inflate away the debt.[2] If inflation has real economic costs, a low credibility government trades off the inflationary incentive of local currency debt against the increased expected default cost of foreign currency debt.[3] In contrast, a credible government optimally borrows in local currency, minimizing expected default costs. On the monetary policy side, we build on a two-period canonical New-Keynesian monetary policy framework (Clarida, Gali, and Gertler 1999, CGG) and its small open economy extensions (Gali and Monacelli 2005). Inflation and output move along an upward-sloping New Keynesian Phillips curve, which is subject to cost-push shocks. A low credibility government can only partially offset cost-push shocks, leading to high inflation recessions and simultaneous falls in bond and stock prices. In contrast, a high credibility government responds to recessionary cost-push shocks by strengthening its commitment to low future inflation, thereby driving up local currency bond prices in recessions. In the model, negative bond-stock betas therefore occur as a result of low monetary policy credibility.

The theoretical predictions of the model are as follows. Governments with more credible monetary policies borrow more in local currency. In addition, high credibility leads to more

[2]There is also a large literature on the optimality of inflationary taxation in the domestic setting (Calvo 1978, Barro 1983, Barro and Gordon 1983, Kydland and Prescott 1977, Bohn, 1988, 1990, Calvo and Guidotti 1993). The incentive to create surprise inflation is plausibly even stronger when debt is held by international agents (Bohn 1991).

[3]While we model the costs of FC debt by assuming that more FC debt increases sovereign default risk, we think of these default costs as a stand-in for a wider class of potential losses from FC debt. In particular, we currently do not model the potential gains or losses from state-contigency that a country may experience from borrowing in FC. Similarly, shocks to the exchange rate could potentially increase the volatility of debt service costs for FC debt. While we currently refer to the welfare costs of FC debt as "default costs," we think of this as potentially capturing a wider range of losses from FC borrowing.

positive comovement between inflation and output expectations, more negative comovement between LC bond returns and local stock returns, and more positive comovement between LC bond returns and sovereign default risk. In addition to matching the observed relationship between the cyclicality of nominal risk and bond returns, the model also delivers predictions for the level of inflation and default risk consistent with the data. The level of inflation and sovereign default risk decreases with monetary policy credibility, which is strongly supported by the data.

This paper most closely relates to a recent literature on inflation commitment and debt limits when the debt denomination is exogenous (Araujo, Leon, and Santos 2013, Aguiar, Amador, Farhi and Gopinath 2014, Chernov, Schmid, and Schneider 2015, Sunder-Plassmann 2014, Bacchetta, Perazzi, and Van Wincoop 2015, Du and Schreger 2015b, Corsetti and Dedola 2015). Barro (1997) discusses the costs and benefits of a government borrowing using nominal bonds to try to exploit the covariance between government purchases and inflation. Alfaro and Kanzcuk (2010) analyze the welfare implications of real and nominal borrowing in a quantitative framework. Diaz-Gimenez et al. (2008) examine how the currency denomination of sovereign debt interacts with the time consistency of optimal monetary policy. We expand on these papers along two dimensions. First, we model the government's optimal time-varying share of internationally held local currency debt. Second, we allow the central bank to engage in optimal forward guidance with partial credibility. While the literature has considered dollarization or monetary unions as commitment devices for central banks (i.e. Obstfeld 1997), we consider how the government optimally chooses the denomination of sovereign debt to try to overcome its limited monetary policy credibility.

We add to the literature on government debt and inflation with exogenous debt denomination (Sargent and Wallace 1981, Leeper 1991, Sims 1994, Woodford 1995, Cochrane 2001, Davig, Leeper, and Walker 2011, Cochrane 2011, Niemann, Pichler, and Sorger 2013), by considering the government's optimal portfolio of LC and FC debt issuance. In addition, the paper is related to a recent literature on time-varying bond risks (Baele, Bekaert, and

Inghelbrecht 2010, Andreasen 2012, David and Veronesi 2013, Campbell, Sunderam, Viceira 2014, Campbell, Pflueger, and Viceira 2015, Song 2015, Ermolov 2015), that is primarily focused on the US and the UK. This paper differs from the previous literature, in that we focus on governments' optimal debt issuance as an important margin for bond risks.

The structure of the paper is as follows. In Section 2, we present the new stylized fact on the relationship between the cyclicality of nominal bond risk and shares of nominal debt in sovereign portfolios. In Section 3, we present a New Keynesian model with a government debt portfolio choice and sovereign default risk. In Section 4 we solve the model and discuss the model's implications and comparative statics. In Section 5, we test additional implications of the model explanations. Section 7 concludes.

2 Nominal Bond Risks and Sovereign Debt Portfolios

In this section, we establish the relationship between nominal bond risk and the share of nominal debt in the sovereign debt portfolio. We first describe the data and variable construction used in our analysis and present some summary statistics by market and developed market groups. We then show strong correlation among nominal risk measures and their relationship with sovereign debt portfolios.

2.1 Data and Variable Construction

We focus on inflation and default dynamics, bond risks and sovereign debt portfolios in 11 developed markets (Australia, Canada, Denmark, Germany, Japan, New Zealand, Norway, Sweden, Switzerland, United States and United Kingdom) and 19 emerging markets (Brazil, Chile, China, Colombia, Czech Republic, Hungary, Indonesia, Israel, Malaysia, Mexico, Peru, Philippines, Poland, Russia, Singapore, South Africa, South Korea, Thailand and Turkey).

For LC bond yields, we use primarily Bloomberg fair value (BFV) curves. BFV curves are estimated using individual LC sovereign bond prices traded in secondary markets. Since sufficient numbers of bonds spanning different maturities are needed for yield curve estimation, the availability of the BFV curve is a good indicator for the overall development of the LC nominal bond market. Countries such as Argentina, Uruguay and Venezuela only have a handful of fixed-rate bonds and hence do not have a BFV curve. As for most emerging markets in our sample BFV curves are available starting in the mid-2000s, we focus on the period 2005-2014 to maintain a balanced panel.

To measure default risk, we use sovereign credit default swap spreads (CDS) from Markit. Sovereign CDS contracts offer insurance for investors in the event of sovereign default.[4] All sovereign CDS contracts are denominated in U.S. dollars and hence CDS spreads offer an approximation for the shadow costs of issuing a U.S. dollar debt for different sovereign issuers.[5]

To measure inflation risk and the perceived cyclicality of inflation, we use realized inflation from Haver and inflation forecasts from Consensus Economics, respectively. Finally, we measure the share of nominal debt in total sovereign debt portfolios with data from BIS Debt Securities Statistics, OECD Central Government Debt Statistics, and several individual central banks.

2.1.1 Bond Bond Risks: Bond-Stock and Bond-CDS Betas

Given the log yield on an n-year bond traded at par $y_{nt} = \log(1+Y_{nt})$, the log holding period return on the bond is given by

$$r^b_{n,t+\Delta t} \approx D_n y_{nt} - (D_n - \Delta t) y_{n-1,t+\Delta t},$$

where $D_n = \frac{1-(1+Y_{cnt})^{-n}}{1-(1+Y_{cnt})^{-1}}$ is the duration of the bond (Campbell, Lo and MacKinlay, 1997). We approximate $y_{n-\Delta t,t+\Delta t}$ by $y_{n,t+\Delta t}$ for the quarterly holding period. We let y_{t1} denote

[4]For developed countries, CDS contracts insure against defaults on all Treasury bonds denominated in local currencies under domestic law. However, in emerging markets, CDS contracts are exclusively linked to external debt denominated in foreign currencies.

[5]US sovereign CDS contracts are denominated in euros.

the three-month T-bill yield and then the excess return on LC bonds over the short rate is given by

$$rx^b_{n,t+\Delta t} = r^b_{n,t+\Delta t} - y_{t1}.$$

From a dollar investor's perspective, we can rewrite the excess return as

$$rx^b_{n,t+\Delta t} = [r^b_{n,t+\Delta t} - (y_{t1} - y^*_{t1})] - y^*_{t1}.$$

The dollar investor can hedge away the currency risk of the holding period Δt by going long a U.S. T-bill and shorting a LC T-bill with the same market value as the LC bond. By doing so, any movement in the spot exchange rate of the LC has the same offsetting first-order impact on the bond position and the local T-bill position and hence cancels out. After hedging currency risk for the holding period, the dollar investor bears duration risk of the LC bond.

We define the local equity excess returns as the log return on local benchmark equity over the three-month LC Treasury bill:

$$rx^m_{t+\Delta t} = (p^m_{t+\Delta} - p^m_t) - y_{t1},$$

where p^m_t denotes the log benchmark equity return index at time t. Country subscripts are suppressed to keep the notation concise. We then compute the local bond-stock beta $\beta^{b,s}$ by regressing LC bond excess returns $rx^b_{t+\Delta t}$ on local equity excess returns $rx^s_{t+\Delta t}$:

$$rx^b_{t+\Delta t} = \alpha + \beta^{b,s} rx^s_{t+\Delta t} + \epsilon_t.$$

Bond-stock betas measure the risk exposure of LC bond returns on local equity returns. In addition, we also compute the bond-CDS beta as the regression coefficient of LC bond excess returns on changes in CDS spreads:

$$rx^b_{t+\Delta t} = \alpha + \beta^{b,cds}\Delta cds_{t,t+\Delta t} + \epsilon^L_t.$$

2.1.2 Cyclicality of Inflation Expectations: Forecast Beta

To measure the expected pro-cyclicality of inflation expectations, we regress the change in the CPI inflation rate predicted by forecasters on the change in their predicted real GDP growth rate. Each month, professional forecasters surveyed by Consensus Economics forecast inflation and GDP growth for the current and next calendar year. We use revisions of inflation and GDP forecasts each month relative to forecasts made three months ago to infer shocks to investors' expectation of inflation and output. We pool all revisions for 2006 through 2013 (so that the forecasts themselves were all made post-2005), and run the country by country regressions

$$\Delta\tilde{\pi}_t = \beta_0 + \beta^{\pi,gdp}\Delta g\tilde{d}p_t + \epsilon_t, \tag{1}$$

where t indicates the date the revision is made. The revisions to inflation forecasts ($\Delta\tilde{\pi}_t$) and GDP growth forecasts ($\Delta g\tilde{d}p_t$) are measured as percentage changes of forecasts made three months before. The coefficient $\beta^{\pi,gdp}$ measures the cyclicality of inflation expectations and is the coefficient of interest.

Because forecasts are made for calendar years, the forecast horizon can potentially vary. Consensus forecasts the annual inflation rate up to two years in advance. This means that in January 2008, the forecast of calendar year 2008 inflation is effectively 11 months ahead and the forecast of calendar year 2009 is 23 months. We focus on revisions to the two-year forecast in order to minimize variation in the forecast horizon.

2.1.3 Nominal Debt Shares

For developed countries, we construct the share of nominal debt based on the OECD Central Government Debt Statistics and individual central banks, which directly report the instrument composition of debt securities outstanding issued by the central government.

For emerging markets, we measure the share of nominal debt in sovereign debt portfolios using BIS Debt Securities Statistics. Table 16C of the Debt Securities Statistics reports the instrument composition for outstanding domestic bonds and notes issued by the central government (D_t^{Dom}) starting in 1995. Table 12E of the Debt Securities Statistics reports total international debt securities outstanding issued by the general government (D_t^{Int}). For emerging markets, as the vast majority of international sovereign debt is denominated in foreign currency, and local governments rarely tap international debt markets, D_t^{Int} offers a very good proxy for central government foreign currency debt outstanding. Data for developed countries from are from individual central banks or the OECD. The share of nominal debt is computed as the ratio of the fixed-coupon domestic sovereign debt outstanding (D_t^{Int}) over the sum of domestic and international government debt:

$$\alpha_t^{Nom} = \frac{D_t^{Dom,Fix}}{D_t^{Dom} + D_t^{Int}}.$$

Inflation-linked debt, floating-coupon debt and FC debt are all treated as real liabilities.

2.2 Summary Statistics

Table 1 reports summary statistics for inflation, inflation expectations, CDS spreads, nominal bond yields, bond-stocks betas, bond-CDS betas, inflation-output forecast betas, and nominal debt shares by developed and emerging market groups. Compared with developed markets, emerging market CDS spreads are 91 basis points higher on average. While CDS spreads across countries share a large common component (Longstaff, Pan, Pedersen, and Singleton 2011, Ang and Longstaff 2013), our empirical results focus on the substantial cross-country differences in the level of CDS spreads and bond-CDS betas. Emerging market realized inflation is 2.4 percentage points higher and survey-based expected inflation is 2.0 percentage points higher. In addition, inflation is expected to be less pro-cyclical in emerging markets than in developed countries.

For nominal bonds, five-year nominal yields are 3.4 percentage points higher in emerging markets than in developed markets. Nominal bond returns are counter-cyclical in developed markets, as evident from negative bond-stock betas and positive bond-CDS betas. By contrast, nominal bond returns are pro-cyclical in emerging markets. Finally, the share of nominal debt in total debt portfolios is 26 percentage points higher in developed than in emerging markets.

2.3 Co-movements among Nominal Risk Betas

Figure 1 shows the strong co-movement between bond-stock betas and bond-CDS betas in Panel (A) and between bond-stock betas and inflation forecast betas in Panel (B). Developed markets are denoted by green dots and emerging markets are denoted by red dots. We can see from the y-axis that all developed markets have negative bond-stock betas during the past decade. Among emerging markets, bond-stock betas range from slightly negative 0.07 for Thailand to positive 0.32 for Turkey.

The cross-sectional pattern for bond-stock betas maps maps almost exactly to the pattern for bond-CDS betas. In Panel (A), we can see that countries with high nominal bond betas tend to have low bond-CDS betas, which implies nominal bonds have high excess returns when when stock market returns are high and CDS spreads are narrow. For the investor's perspective, nominal bonds hedge stock market and sovereign default risk for developed markets, whereas nominal bonds can be risky assets with respect to stock market and sovereign default risk for emerging markets. From the sovereign issuer's perspective, nominal bonds are risky for developed markets and the debt burden is higher in bad times, but can be good hedge for emerging markets with negative bond-stock betas and positive bond-CDS betas as the debt burden is lower in bad times.

Since changes to inflation expectations are an important driver of nominal bond returns, we expect the cyclicality of nominal bond returns to be highly correlated with the cyclicality of inflation expectations. Panel (B) shows a strong negative relationship between bond-stock betas and inflation forecast betas across countries. In other words, in countries with more negative bond-stock betas, inflation is expected to be more pro-cyclical with respect to output. During bad times, lower inflation expectations lead to higher nominal bond returns.

2.4 Relationship between Nominal Risk Betas and Sovereign Debt Portfolios

Figure 2 displays the relationship between nominal risk betas and the share of nominal debt in sovereign debt portfolios. The share of nominal debt varies substantially across countries and is systematically correlated with nominal risk betas. In particular, we find that countries with higher bond-stock betas, lower bond-CDS betas and lower inflation forecast betas tend to have lower shares of nominal sovereign debt. Thus, countries with more pro-cyclical bond returns and less pro-cyclical inflation expectations use more nominal debt. Emerging markets have lower nominal debt shares and more pro-cyclical nominal risk, whereas developed countries have high nominal debt shares and more counter-cyclical nominal risk.

The negative relationship between nominal debt shares and the pro-cyclicality of nominal risk is at first puzzling since it is odds with the prediction from a standard portfolio model with exogenous monetary policy. In particular, if the marginal cost of transferring resources to foreign bond holders is highest in recessions, the government should want to shift debt repayments towards good states of the world. In countries with positive bond betas, such as Brazil or Turkey, the real value of nominal debt repayments is low in bad states of the world, which should make nominal debt an attractive way of borrowing. The gain from consumption smoothing across the states using nominal debt is the greatest for countries with the most pro-cyclical nominal bond returns, but on the contrary, these countries have the lowest shares of nominal debt in their portfolios.

In the following section, we show that we can resolve the puzzle between nominal risk betas and sovereign debt portfolios using a model with endogenous monetary policy under imperfect monetary policy credibility.

3 Model

This section describes the model assumptions and setup. We study a two-period version of the standard New Keynesian model. We add two new features to this standard model. First, we allow the government to optimally choose the currency denomination of sovereign debt. Second, we model government credibility by introducing a parameter that allows us to vary the probability that the government implements its promised future policy or implements discretionary policy.

This means that in addition to setting short-term nominal interest rate policy, the government also decides in which currency to fund itself. The government's optimal liabilities problem has parallels to the international household portfolio choice problem (Devereux and Saito 1997, Campbell, Serfaty-De Medeiros, and Viceira 2010, Devereux and Sutherland 2011, Evans and Hnatkovska 2014), but differs in that the government's debt portfolio can affect future monetary policy and default.

In order to decide in which currency to borrow, the government trades off the increased sovereign default risk from borrowing using FC debt with the temptation for future inflation from using LC debt. This trade-off is very different depending on the level of the government's credibility and the interactions between debt denomination and monetary policy will generate a host of predictions that we will discuss and test in sections 3 and 4.

3.1 Setup and Timing

The model has two time periods, as illustrated in Figure 2. In period 1, the government has no debt outstanding. After observing the period 1 cost-push shock, it chooses period 1 monetary policy and the sovereign debt portfolio. The government also determines a contingent plan for period 2 monetary policy, knowing that it will only be able to implement this plan probability p. This probability p that the government sticks to its announced plan is how we parameterize central bank credibility. It can be thought of as capturing the effectiveness of institutions in overcoming the incentive problems often faced by central banks, as in Persson and Tabellini (1993).

In period 2, the government simply implements the contingent plan with probability p. However, with probability $1 - p$ the government acts myopically.[6] A myopic government faces an incentive to inflate away LC bonds held by foreigners. Finally, at the end of the period the government defaults or repays the debt. Sovereign default is exogenous and the probability of default depends on the debt composition and will be discussed in detail below.

3.2 Debt Issuance

Let D_1^{LC} and D_1^{FC} denote the face values of LC and FC debt issued in period 1 and maturing in period 2. We use q_1^{LC} and q_1^{FC} to denote the corresponding prices per unit of face value.

FC and LC debt differ in terms of the real repayment in case of no default. While the government is required to repay FC bond holders their real initial face value, the required payments to LC bond holders decrease with inflation. To preserve tractability and focus on the first-order effect of inflation surprises on bond returns, we approximate real repayments to LC bond holders log-linearly around conditional expected inflation

$$exp(-\pi_2) \quad \approx \quad exp(-E_1\pi_2)\,(1 - (\pi_2 - E_1\pi_2))\,. \tag{2}$$

[6] Calvo and Guidotti (1993) briefly discuss how an extension of their benchmark model with "incomplete precommitment" with a similar structure, but do not look at empirical implications for inflation-cyclicality.

To focus the analysis on the government's allocation decision across LC and FC debt, we abstract from intertemporal consumption decisions, taking total real borrowing as given. Denoting the real financing need by V, the government chooses debt issuance subject to the budget constraint

$$q_1^{FC} D_1^{FC} + q_1^{LC} D_1^{LC} \quad = \quad V. \tag{3}$$

The assumption (3) can be justified if the government either needs to finance an exogenous path of aggregate public consumption purchases (Obstfeld 1997) or if it needs to borrow a constant amount in order to invest in the country's decreasing returns to scale productive technology (Grossman and Van Huyck 1988).

Letting P_1 denote the expected default probability. With risk-neutral international investors and purchasing power parity, FC and LC bond prices are equal to the discounted expected payoff on the debt:

$$q_1^{FC} \quad = \quad \beta(1 - P_1), \tag{4}$$

$$q_1^{LC} \quad = \quad \beta(1 - P_1) exp(-E_1 \pi_2). \tag{5}$$

For expressing the model solution, it is convenient to define

$$s_1 \quad = \quad D_1^{LC} \left(1 - P_1^d\right) exp\left(-E_1 \pi_2\right). \tag{6}$$

The share of real funds raised as LC debt is closely related to s_1 and given by $\frac{s_1}{V}$. In an abuse of notation, we also refer to s_1 as the "local currency debt share".

3.3 Government Objective Function

The government's objective function combines a standard monetary policy objective to smooth fluctuations in the output gap and inflation with a desire to minimize debt repayments and default costs. Rather than explicitly deriving the objective function from microfoundations, we build on Woodford (2003, Chapter 6), who formally derives a second-order Taylor expansion to consumer utility in a monetary policy model with Calvo (1983) price setting. The period t loss function is given by

$$\begin{aligned} L_t \quad = \quad & \underbrace{\alpha^x x_t^2 + \alpha^\pi \pi_t^2}_{\text{Monetary Policy Criterion}} \quad + \underbrace{(1 - P_{t-1})\left(D_{t-1}^{FC} + D_{t-1}^{LC} exp(-E_{t-1}\pi_t)(1 - (\pi_t - E_{t-1}\pi_t))\right)}_{\text{Real Debt Repayment}} \\ + \quad & \underbrace{Cost_{t-1}}_{\text{Expected Default Cost}} \quad , \end{aligned} \tag{7}$$

where x_t is the log output gap and π_t is log inflation.

The first term in the loss function captures losses due to price-setting frictions and monopolistically competitive firms. As in Woodford (2003, Chapter 6), welfare depends quadratically on inflation and the output gap and can be thought of as a second-order approximation to consumer welfare. Since in period 1 the government has no debt outstanding, this is the only term in the period 1 loss function. Intuitively, the output gap enters quadratically into the monetary policy criterion, because firms need labor to produce output and worker-consumers are close to their optimal consumption-leisure trade-off. In the presence of price-setting frictions inflation is costly, because it distorts firms' prices and hence quantities from the first-best. Woodford (2003) suggests output and inflation weights for plausible price-setting frictions of $\alpha^x/\alpha^\pi = 0.05$.

The real debt repayment term captures expected real payoffs to foreign bondholders with the approximation (2). Ex-post inflation redistributes wealth from foreign bond holders to domestic consumers. Real debt repayments therefore decrease in inflation and more so when the government has more LC debt outstanding. The third term in the loss function captures expected losses from default.

The government minimizes the discounted sum of period losses

$$\underset{\pi_1, x_1, D_1^{FC}, D_1^{LC}, \pi_2, x_2}{min} E_1 \sum_{t=1}^{2} \beta^t L_t, \tag{8}$$

subject to x_t and π_t satisfying a New-Keynesian Phillips Curve and the budget constraint (3).

3.4 Irrelevance Case

First, we solve a very simple case without default and no real economic costs of inflation, i.e. $P_1 = Cost_1 = \alpha^x = \alpha^\pi = 0$. In this case, a result in the spirit of Modigliani and Miller (1958) holds and the government is indifferent between issuing LC and FC debt.

Assume that expected inflation is a function of s_1

$$E_1\pi_2 \quad = \quad E_1\pi_2(s_1). \tag{9}$$

An upward-sloping relation of the form (9) arises within the full model, because the incentive to inflate away debt increases with the LC debt share.

Debt repayments are transfers from domestic agents to foreign bond holders and the risk-neutral government minimizes expected debt repayments. The loss function hence becomes

$$L_t \quad = \quad -\left(D_1^{FC} + D_1^{LC} exp(-E_1\pi_2(s_1))\right). \tag{10}$$

Substituting $P_1 = 0$ into the pricing relations (4)-(5) and the budget constraint (3) gives

$$L_t \quad \equiv \quad -\beta^{-1}V. \tag{11}$$

The government's loss function is hence constant and in particular independent of expected inflation and the share of debt issued in local currency.

Intuitively, higher expected period 2 inflation depresses the period 1 price of LC debt, thereby reducing the government's revenue per face value of LC debt, which makes LC debt less attractive. On the other hand, higher inflation expectations reduce the government's period 2 real debt service for LC debt, making LC debt more attractive. The two effects cancel exactly, leaving the government indifferent between issuing LC and FC debt.

The irrelevance case illustrates that any non-degenerate solution for optimal debt portfolio choice must be driven by a trade-off between distortionary inflation and default costs. We turn to the macroeconomic dynamics and default costs next.

3.5 Macroeconomic Dynamics and Monetary Policy

Output and inflation dynamics build on the standard log-linearized New Keynesian model with optimal monetary policy (Clarida, Gali, and Gertler 1999, CGG).[7] The output gap – the difference between actual real output and potential output with no nominal rigidities – is pro-cyclical and serves as the business cycle variable in our model. The dynamics for the log output gap x_t, log inflation π_t and the log nominal interest rate i_t satisfy the consumer's Euler equation and a log-linearized forward-looking Phillips curve.

For $t = 1, 2$ we have that

$$x_t = E_t x_{t+1} - \psi \left[i_t - E_t \pi_{t+1} \right], \tag{12}$$

$$\pi_t = \lambda x_t + \beta E_t \pi_{t+1} + u_t. \tag{13}$$

The Euler equation (12) arises from the consumer's intertemporal tradeoff. In New Keynesian models, it is standard to derive the forward-looking Euler equation (12) by assuming power utility and setting consumption equal to the output gap.

Relation (13) is the New Keynesian Phillips curve (PC), capturing firms' price-setting and production decisions. Current period inflation increases with the output gap and future expected inflation. A forward-looking PC of the form (13) can be derived if firms update their prices infrequently as in Calvo (1983). The shock u_t simultaneously increases inflation and decreases output and captures cost-push shocks, wage-markup shocks, or productivity

[7] Gali and Monacelli (2005) obtain analogous expressions for inflation and output dynamics and welfare in a small open economy model. They find that degree of openness and the substitutability of goods across countries may affect the slope of the Phillips Curve relation, but the basic functional forms also are unchanged.

shocks.

Monetary policy determines the nominal policy rate i_t, thereby setting output according to the Euler equation. It can therefore achieve any output-inflation tradeoff along the PC (13) by choosing the appropriate nominal interest rate.

Cost-push shocks follow an AR(1) process with autocorrelation ρ_u

$$u_t = \rho_u u_{t-1} + \varepsilon_{u,t}, \tag{14}$$

$$\varepsilon_{u,t} \overset{iid}{\sim} N(0, \sigma_u^2). \tag{15}$$

To more clearly exhibit the mechanism at work, we consider a two-period version of the standard New Keynesian macroeconomic model, as in Romer (2006). We set $u_0 = 0$ without loss of generality. We assume that inflation and the output gap are constant at zero from period 3 onwards

$$\pi_t = 0 \ \forall \ t \geq 3, \tag{16}$$

$$x_t = 0 \ \forall \ t \geq 3. \tag{17}$$

Besides clarifying the exposition, the assumption (16) is plausible if a partially credible government controls policy over the medium run, but takes long-run inflation as given. A further advantage is that a finite-period model always has a unique solution. This need not be the case for infinite-period New Keynesian models, which may have multiple equilibria (Evans 1986, Uhlig 1999, Cochrane 2011).

3.6 Expected Default Costs

Next, we specify default probabilities and costs. Expected default costs are a function of the initial debt issuance decision and increase more sharply in FC than in LC debt. Expected default costs are minimized when the government is entirely financed by LC debt and increases convexly as the government finances itself with a larger share of FC debt, capturing key features of sovereign and corporate default models (Merton 1974, Aguiar and Gopinath 2006, Arellano 2008). While we refer to our reduced form loss from FC debt as a "default cost," these losses from FC debt could come through a variety of channels, such as the presence of exchange rate shocks that increase the volatility of real debt service for FC debt.

Eichengreen and Hausmann (2005) argue forcefully that issuing FC debt exposes emerging countries to increased default risk, with accompanying default costs. Moreover, the costs of issuing a small amount of FC debt would appear small, so we model expected default costs (up to a constant that does not matter for optimal policy) as an decreasing and convex function in the LC debt share

$$Cost_1 = -\frac{c}{2(\alpha^{\pi}\lambda^2 + \alpha^x)}s_1 + \frac{d}{4(\alpha^{\pi}\lambda^2 + \alpha^x)}s_1^2, \tag{18}$$

where both c and d are positive and $(\alpha^{\pi}\lambda^2 + \alpha^x)$ is a positive scaling factor.

3.6.1 Default Probability and Cost Upon Default

We can decompose (18) into the product of the default probability and the cost upon default, where both quantities are functions of the face values D^{FC} and D^{LC}. However, only the product (18) enters into welfare considerations and optimal debt issuance, so the specific decomposition is much less crucial for our predictions and should be regarded as an example.

We model the default probability as an increasing function in the weighted sum of the face value of FC debt D_1^{FC} and the expected real face value of LC debt $D_1^{LC} exp\left(-E_1\pi_2\right)$. The weights are given by $\theta^{FC} > \theta^{LC} \geq 0$, implying that the default probability increases more sharply in FC debt than in LC debt. We assume that the default probability conditional on time 1 information is given by

$$P_1 \quad = \quad \frac{\theta^{FC} D_1^{FC} + \theta^{LC} exp\left(-E_1 \pi_2\right) D_1^{LC}}{1 + \theta^{FC} D_1^{FC} + \theta^{LC} exp\left(-E_1 \pi_2\right) D_1^{LC}}. \tag{19}$$

Figure 3, Panel (B) shows that the functional form (19) satisfies several desirable properties. The red solid line varies D^{FC} holding D^{LC} constant at zero and the blue dashed line varies $D^{LC} exp\left(-E_1 \pi_2\right)$ holding D^{FC} constant at zero.

We model real economic costs upon default as increasing with the total expected real face value of debt, but bounded above by a constant a, consistent with evidence that larger sovereign defaults are costlier (Cruces and Trebesch 2013). For some $b > 0$ and $a \geq \frac{b}{\beta^{-1} V}$, real default costs are

$$a - b \frac{1}{D_1^{FC} + D_1^{LC} exp\left(-E_1 \pi_2\right)}. \tag{20}$$

Expected default costs are real default costs (39) multiplied by the default probability (19). We formally assume full default, so investors recover nothing in default. However, optimal debt issuance would be unchanged if we assumed instead that expected default costs (39) are net of investors' expected default recovery. Intuitively, investors' expected recovery raises bond prices at issuance, allowing the government to raise more funds for each dollar of face value.

Substituting in the budget constraint (3), we can then write expected default costs in the form (18) (up to a constant) with

$$c \quad = \quad 2(\alpha^\pi \lambda^2 + \alpha^x)(\theta^{FC} - \theta^{LC}) \left(a + 2b\theta^{FC} - \frac{b}{\beta^{-1} V} \right), \tag{21}$$

$$d \quad = \quad 4(\alpha^\pi \lambda^2 + \alpha^x) \frac{b(\theta^{FC} - \theta^{LC})^2}{\beta^{-1} V}. \tag{22}$$

The government defaults on all its liabilities simultaneously. In practice, governments frequently default on LC and FC sovereign debt simultaneously (Du and Schreger 2015a).

A theoretical literature, beginning with Broner, Martin, and Ventura (2010) and Broner and Ventura (2011), argues that secondary markets effectively prevent governments from defaulting only on one class of bondholders.[8]

3.7 Bond and Stock Returns

In keeping with the qualitative nature of the model, we make the simplest possible assumptions to price bonds and stocks. Bonds and stocks are priced by a risk-neutral international investor with a constant discount factor β and the exchange rate obeys purchasing power parity.

Log excess returns on a one-period LC bond are given by

$$\begin{aligned} & r_1^{LC} - E_0 r_1^{LC} \\ = \quad & -\left(E_1 - E_0\right)\left(q_1^{LC} - log(1 - P_1)\right), \\ = \quad & -\left(E_1 - E_0\right)\left(\pi_2 - log(1 - P_1)\right) \end{aligned} \tag{23}$$

Positive LC bond excess returns hence reflect either a decline in period 2 inflation expectations or a decline in the default probability P_1.

We model stocks as a pro-cyclical asset by assuming that dividends are given by

$$div_t = x_t. \tag{24}$$

We approximate log equity excess returns using Campbell's (1991) loglinear decomposition. For a log-linearization constant ρ close to one, log equity excess returns are

$$r_1^e - E_0 r_1^e = \left(E_1 - E_0\right) \sum_{j=0}^{2} \rho^j \Delta x_{1+j}, \tag{25}$$

$$= \left(1 - \rho\right)\left(E_1 - E_0\right)\left(x_1 + \rho x_2\right). \tag{26}$$

[8] While this literature focuses on defaulting on foreigners versus residents, a similar argument may apply to LC and FC debt.

Equity excess returns hence increase when there is positive news about the current and future output gaps.

The expression (24) follows the asset pricing literature, which models dividends as a levered claim on consumption (Abel 1990, Campbell 1986, 2003). Small New Keynesian models often set consumption equal to the output gap (CGG), in which case stocks become a levered claim on consumption. While equity prices and returns in the model are highly stylized, the output gap and expected inflation similarly drive equity and bond returns in Campbell, Pflueger, and Viceira's (2015) New Keynesian asset pricing model, which explicitly accounts for the consumption-output gap relation and time-varying risk premia.

4 Model Solution

We solve the model recursively, first solving for the government's optimal period 2 policy and then for optimal period 1 policy.

4.1 No-Commitment Regime

Let π_2^{nc} and x_2^{nc} denote period 2 inflation and the output gap in the no-commitment regime. The solution in the no-commitment regime is particularly simple. Without commitment, the government minimizes period 2 welfare (7) subject to the PC constraint (13). The first-order condition is

$$2\alpha^x \lambda^{-1} x_2^{nc} + 2\alpha^\pi \pi_2^{nc} - s_1 \quad = \quad 0, \tag{27}$$

implying that

$$\pi_2^{nc} \quad = \quad \frac{\lambda^2 s_1 + 2\alpha^x u_2}{2(\alpha^\pi \lambda^2 + \alpha^x)}, \tag{28}$$

$$x_2^{nc} \quad = \quad -\frac{\lambda \alpha^\pi}{\alpha^x} \pi_2^{nc} + \frac{\lambda}{2\alpha^x} s_1. \tag{29}$$

The first-order condition (49) shows that no-commitment inflation increases in the LC debt share s_1. Issuing a higher share of LC debt therefore increases the no-commitment government's incentive to inflate.

Up to an exogenous component that does not affect policy, the weighted sum of output and inflation deviations then becomes

$$\alpha^x \left(x_2^{nc}\right)^2 + \alpha^\pi \left(\pi_2^{nc}\right)^2 = \frac{\lambda^2 s_1^2}{4\left(\alpha^\pi \lambda^2 + \alpha^x\right)}. \tag{30}$$

Figure 3, Panel (C) shows the no-commitment welfare losses (30). Welfare losses increase quadratically in the LC debt share s_1, because a higher LC debt share increases the incentive to inflate away debt.

4.2 Commitment Regime

Next, we solve for the government's optimal period 1 policy and the commitment plan for period 2 inflation and the output gap, which we denote π_2^c and x_2^c. Let ϕ_1 and ϕ_2 denote the Lagrange multipliers for the period 1 and period 2 Phillips Curves. Substituting in the no-commitment solution and again ignoring constants, the government minimizes the

Lagrangian

$$\mathcal{L} = \underbrace{\alpha^x x_1^2 + \alpha^\pi \pi_1^2 + \beta p E_1 \left[\alpha^x (x_2^c)^2 + \alpha^\pi (\pi_2^c)^2\right]}_{\text{Inflation and Output Distortions with Commitment}} \tag{31}$$

$$+ \underbrace{\beta(1-p)\frac{\lambda^2 s_1^2}{4(\alpha^\pi \lambda^2 + \alpha^x)}}_{\text{Inflation and Output Distortions without Commitment}} \tag{32}$$

$$\underbrace{-\beta\frac{c}{2(\alpha^\pi \lambda^2 + \alpha^x)} s_1 + \beta\frac{d}{4(\alpha^\pi \lambda^2 + \alpha^x)} s_1^2}_{\text{Expected Default Cost}} \tag{33}$$

$$+\underbrace{\phi_1 \left[\pi_1 - \lambda x_1 - \beta p E_1 \pi_2^c - \beta(1-p)\frac{\lambda^2 s_1 + 2\alpha^x \rho_u u_1}{2(\alpha^\pi \lambda^2 + \alpha^x)} - u_1\right]}_{\text{Period 1PC}} \tag{34}$$

$$+\underbrace{\beta p \phi_2 \left[\pi_2^c - \lambda x_2^c - u_2\right]}_{\text{Period 2PC}}. \tag{35}$$

Expected period 2 inflation enters into the period 1 PC as a weighted sum of commitment and no-commitment regimes. Rational expectations together with the budget constraint (3) imply that expected debt repayments are constant and hence do not affect optimal policy. The Lagrange multipliers ϕ_1 and ϕ_2 reflect the shadow cost of relaxing the PC constraints in periods 1 and 2, or the marginal costs of adverse supply shocks.

The first-order condition with respect to the LC share is

$$s_1 = \frac{c}{\lambda^2(1-p)+d} + 2\alpha^x \frac{\lambda(1-p)}{\lambda^2(1-p)+d} x_1, \tag{36}$$

The cost of a higher LC share is higher inflation expectations, which enter both into no-commitment inflation and output distortions (32) and into the period 1 PC (34). The benefit of a higher LC debt share is a reduction in expected default costs, as captured by (33). The optimal LC share equates the marginal costs with the marginal benefits. The intercept in (58) increases in p. Intuitively, the higher credibility, the smaller are the costs of LC debt. With full commitment ($p = 1$), the LC debt share s_1 drops out of (32) and (34) and the government chooses s_1 to minimize expected default costs.

Figure 3, Panel (D) shows the costs of LC debt for high credibility (red solid) and low credibility (blue dashed). The optimal s_1 equates the marginal cost with the marginal benefit, which is indicated with black dotted tangency lines. With low credibility, period 2 costs decrease more slowly in the LC debt share, and hence for any given marginal cost the optimal LC debt share is lower.

Next, we need the first-order-conditions for optimal period 1 and period 2 commitment inflation. These are given by

$$\pi_1 = -\frac{\alpha^x}{\lambda\alpha^\pi} x_1, \tag{37}$$

$$\pi_2^c = -\frac{\alpha^x}{\lambda\alpha^\pi} \left(x_2^c - x_1\right). \tag{38}$$

The first-order-condition (38) shows that period 2 commitment inflation is positively related to the period 1 output gap, so commitment inflation is low when the output gap is low. Intuitively, the government seeks to anchor inflation expectations in bad states of the world, thereby mitigating an adverse cost-push shock.

When credibility is high, consumers and investors form inflation expectations largely based on π_2^c and inflation expectations decline when the output gap is low. On the other hand, when commitment is low and consumers and investors put little weight on π_2^c in forming inflation expectations, an inflationary and recessionary cost-push shock is expected to persist and inflation expectations are high when the output gap is low.

4.3 Model Implications

We summarize the model implications in several propositions. Despite its simplicity, the model has numerous testable implications for inflation and output dynamics, bond risks, the sovereign debt portfolio, and default risk. Proofs and closed-form model solutions are provided the appendix.

Primary Implications

1 *The LC bond-stock beta decreases with credibility.*

Stock returns are positively related to current and future expected output gaps and LC bond returns move inversely with expected inflation and the probability of default (see (23) and (26)). Since inflation cyclicality increases with credibility, LC bond betas decrease with credibility. Time-varying default risk further strengthens the negative relation between credibility and bond-stock betas.

2 *The LC debt share increases with credibility.*

One of the key distortions from issuing LC debt is the possibility of inflation when commitment breaks down in period 2. When credibility is high, the government is less concerned about inefficiently high inflation in period 2 and hence issues a larger LC debt share.

Secondary Implications

3 *The level of inflation decreases with credibility.*

When monetary policy is credible, it is unlikely that the government will inflate away LC debt, lowering inflation expectations. Through the New Keynesian PC, inflation today is positively related to inflation expectations, so current inflation decreases in credibility.

4 *The default probability decreases with credibility.*

The default probability increases more steeply in FC debt than in LC debt. Since a credible government issues more LC debt and less FC debt, it has lower default risk.

5 *The expected inflation-output beta increases with credibility.*

When credibility is low, cost-push shocks simultaneously decrease the output gap and increase inflation. The central bank trades off output against current-period inflation through the PC, but it can never reverse the sign of the initial shock. With persistent cost-push shocks, expected inflation also increases and the expected inflation-output beta is negative.

A credible central bank can credibly signal future policy, or engage in forward guidance. Following a positive cost-push shock, the central bank mitigates the increase in inflation and decrease in the output gap by committing to lower future inflation. It follows that optimal forward guidance increases the expected inflation-output gap beta.

6 *Default risk varies counter-cyclically.*

Despite not making any explicit assumptions about the cyclicality of default risk, we obtain the plausible prediction that expected default rises during recessions, consistent with empirical evidence by Tomz and Wright (2007). During recessions, the commitment value of FC debt is especially valuable. The government therefore issues a larger share of FC debt, thereby incurring higher default risk in exchange for lower inflation expectations. It is important to note, however, that this is a different mechanism than what would drive the cyclical properties of default risk in models of strategic sovereign default. In a framework where the government is choosing whether to repay the debt, defaults are more likely in recessions because marginal consumption is high and so the government places a high value on additional resources.

7 *The LC bond-default risk beta increases with credibility.*

This follows from LC bond returns being more countercyclical when credibility is high and default risk being countercyclical.

We contrast these implications again with a version of the model, where the LC debt share is pre-determined and exogenous. With exogenous debt composition, the relation between inflation and LC debt shares is reversed, because a higher exogenous LC debt share leads to higher no-commitment inflation. Both bond-stock betas and bond-default betas are invariant with respect to exogenous LC debt shares, so the model with exogenous LC debt shares implies flat relations in Panels (B) through (D).[9]

5 Additional Implications of the Model

In addition to matching the cyclicality of nominal risk and nominal shares in the sovereign debt portfolios as summarized in Section 2, the model also generates predictions on levels of inflation and default risk. In Figure 5, we plot the correlation between bond-stock betas and bond-CDS betas against CDS spreads and realized inflation. Consistent with the model's prediction, countries with more pro-cyclical bond returns also tend to have higher levels of inflation and default risk.

In addition, Table 2 reports cross-country correlations among levels of inflation and default, nominal risk betas and the share of nominal debt. All measures are highly correlated with each other. The first principal component explains 74% of total variations in all empirical moments. The strong common component of these empirical measures supports a unifying explanation of default, inflation and bond risks. In last row of Table 2, we report the correlation between the first PC and each of the seven individual risk measures. Countries with high first PC scores are associated with high default, inflation risk and nominal bond yields, more counter-cyclical inflation and more pro-cyclical LC nominal bond returns. If we interpret a high PC score as the lack of monetary policy credibility, the last row of Table 2 confirms all propositions of the model listed in Section 4.3. Appendix A uses a text-based measure of monetary policy credibility to provide additional support.

[9]Extending our model to include a stronger incentive to inflate away LC debt in recessions would presumably further widen the contrast between the predictions with endogenous and exogenous LC debt shares, so a model with exogenous LC debt shares might even imply a downward-sloping relation in Panel (A).

6 Alternative Explanations

Having shown that monetary policy credibility generates predictions along a large number of dimensions, we now discuss how this evidence helps us rule out alternative explanations.

6.1 Differential Exposure to Inflationary Shocks

In the model, bond betas and the cyclicality of inflation expectations are the result of monetary policy credibility. However, commodity prices are important for many emerging markets and some developed markets, making some countries more likely to suffer stagflationary recessions than others. More generally, bond betas and expected inflation-output comovements could reflect the dominance of supply and demand shocks rather than monetary policy.

However, if the inflation-output comovement varies across countries for reasons that are exogenous to monetary policy, it is hard to explain the downward-sloping relation between the nominal debt share and bond-stock betas shown in Figure 1 Panel (B). Intuitively, the sovereign's incentive to default is highest when real debt repayments are high relative to the country's output. If default generates deadweight costs, the government should borrow in local currency if this can reduce its expected default costs.

With countercyclical inflation, local currency debt loses in value during recessions, and hence can mitigate default risk when it is highest. With procyclical inflation, the real value of local currency debt is highest in recessions, which would increase default risk. Consistent with this intuition, Kang and Pflueger (2015) show that for corporations, which should take aggregate economic conditions as exogenous, pro-cyclical inflation is associated with higher default risk.

This logic suggests that countries with exogenously countercyclical inflation and positive bond-stock betas should issue local currency debt to minimize default costs. We derive this prediction formally in a simple model in Appendix C. Differential exposure to shocks can therefore not explain our motivating empirical fact in Figure 1 Panel (B).

6.2 Smoothing Debt Repayments

If high taxes relative to potential output lead to distortions and deadweight losses, the fiscal authority should smooth tax rates over time (Barro, 1979) and across states of the world (Bohn, 1990). Governments should hence issue securities that have low real payouts in periods of low output. In that sense, tax-smoothing works as if the government was risk-averse, valuing real payoffs more during recessions.

If inflation is countercyclical, the real value of local currency debt falls in recessions. If tax smoothing is the main driver of government debt portfolio choice, countries with countercyclical inflation and positive bond-stock betas should hence borrow in local currency. In contrast, we see the exact opposite in Figure 1 Panel (B). Introducing a tax or consumption-smoothing motive to our current framework would increase the value of borrowing in local currency.

6.3 Strategic Inflation

In order to exhibit clearly the key mechanisms, our model does not include a strategic inflation motive. However, if surprise inflation reduces the real debt burden of local currency debt and reduces default risk (Fisher, 1933), countries local currency debt might use inflation to avoid costly default (Du and Schreger, 2015b). Extending the main model along this dimension would further strengthen the no-commitment government's incentive to inflate away local currency debt, and hence the model's main mechanism. While this additional incentive might matter quantitatively, it is unlikely that this would alter the qualitative model predictions.

7 Conclusion

This paper argues that differences in monetary policy credibility explains the relationship between sovereign debt portfolios and government bond risks across countries. By endogenizing both the business cycle dynamics and the currency choice of sovereign debt, our simple framework gives rise to a number of testable predictions. The key contribution of the paper is to demonstrate how a single change, an increase in monetary credibility, can explain a host of patterns, from the currency denomination of sovereign debt to the cross-country heterogeneity in bond-stock covariances. The empirical support that we find for the testable predictions of model provides strong evidence in favor of the proposed channel.

Our paper is, however, silent on the reason for the increase in central bank credibility. Understanding why some countries have been able to develop institutions that allowed the central bank to become more credible is an obvious direction for future research. Connecting the results in this paper to the earlier theoretical literature on central bank institutional design, such as Persson and Tabellini (1993) and Walsh (1993), may be promising.

The framework's simplicity also presents opportunities for future research to build on the model along several dimensions. First, investors in the model are risk-neutral, but risk premia are likely to be quantitatively important for bond-stock comovements and the international term structure of interest rates (Campbell, Pflueger, and Viceira 2015). Second, we model the government's objective function and type as perfectly known. With uncertainty about the central bank's inflation target (Orphanides and Williams 2004) or the central bank's type (Backus and Driffil 1985, Barro 1986), policy uncertainty might be reflected in asset prices (Pastor and Veronesi 2012, 2013).

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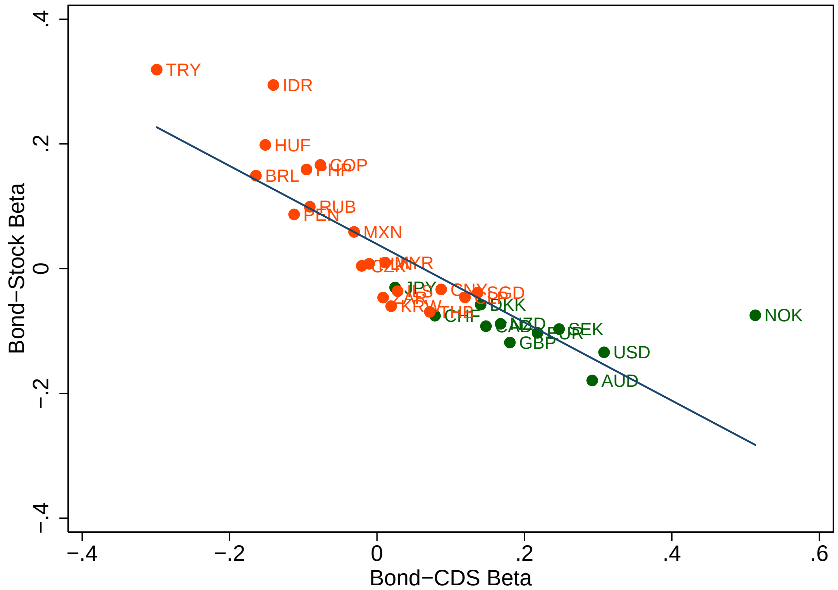
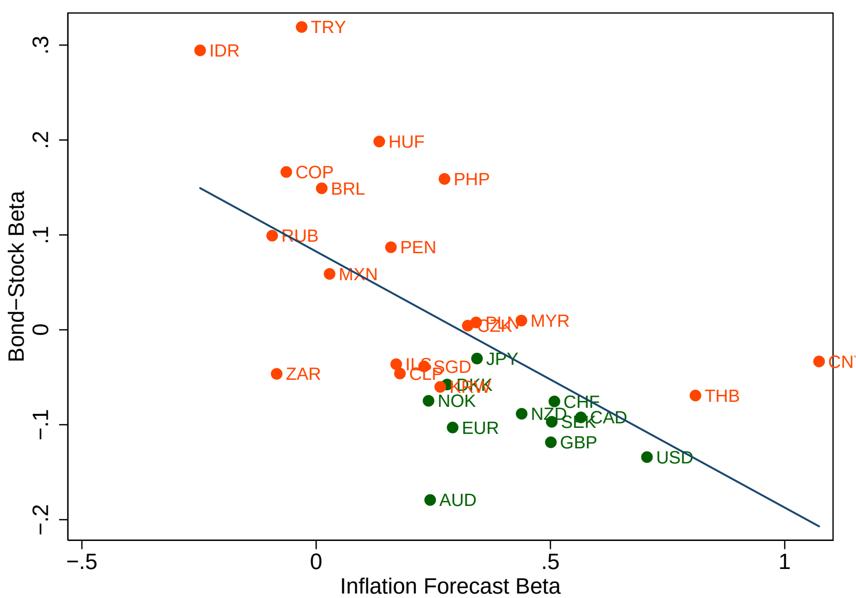
Figure 1: **Comovement Among Nominal Risk Betas**

(A) Bond-Stock Betas v.s. Bond-CDS Betas



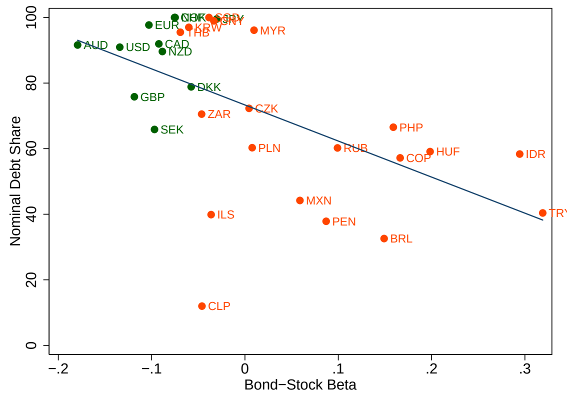
(B) Bond-Stock Betas v.s. Inflation Forecast Betas



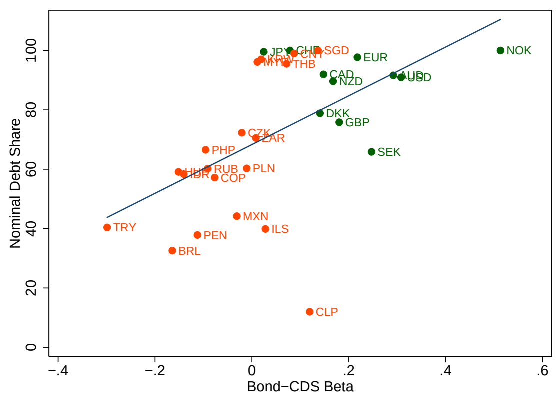
Note: Panel (A) plots the nominal bond-stock betas on the y-axis and nominal bond-CDS betas on the x-axis. Panel (B) plots the nominal bond-stock betas on the y-axis and expected inflation-output betas on the x-axis. Developed markets are denoted by green dots and emerging markets are denoted by red dots. The three-letter currency code is used to label countries. More details on variable definitions can be found in Section 2.1.

Figure 2: **Nominal Debt Shares and Nominal Risk Betas**

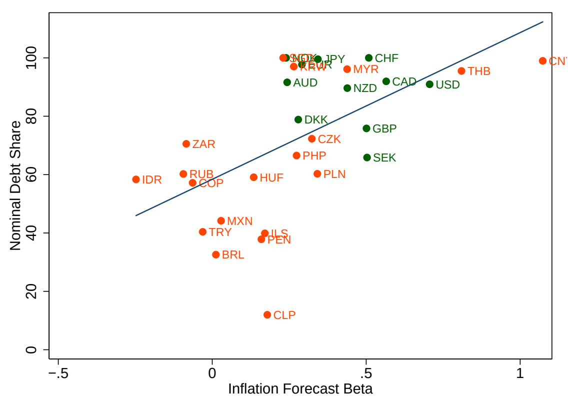
(A) Nominal Debt Share v.s. Bond-Stock Beta



(B) Nominal Debt Share v.s. Bond-CDS Beta

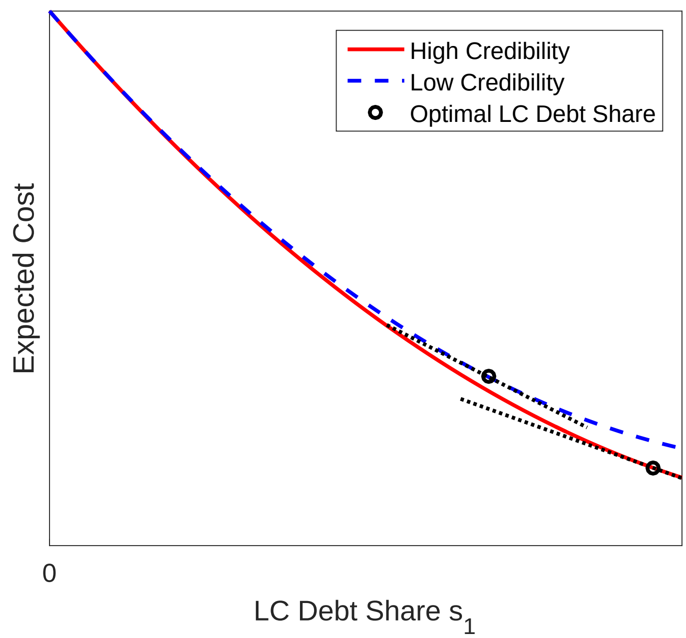


(C) Nominal Debt Share v.s. Inflation Forecast Beta



Note: Panels (A) (B) and (C) plot the share of nominal debt in the sovereign debt portfolio on the y-axis against bond-stock betas, bond-CDS betas and expected inflation-output betas, respectively. Developed markets are denoted by green dots and emerging markets are denoted by red dots. The three-letter currency code is used to label countries. More details on variable definitions can be found in Section 2.1.

Figure 3: **Debt Issuance Trade-Off**



Note: This figure shows the combined expected period 2 cost, defined as the sum of expected default costs and the cost of ex-post inflation, with high credibility (red solid) and low credibility (blue dashed). The figure indicates optimal LC debt shares. At the optimum, the marginal expected period 2 benefit of increasing the LC debt share, indicated by dotted black tangency lines, must equal the marginal period 1 cost of increasing the LC debt share.

Figure 4: **Model Timeline**

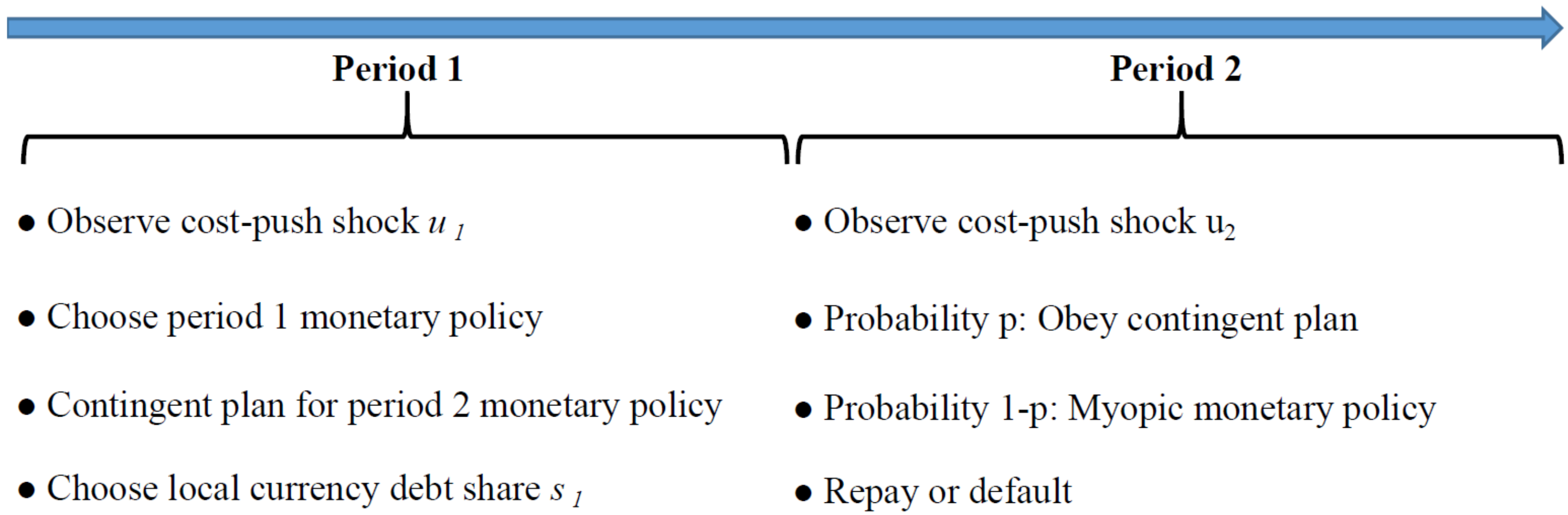
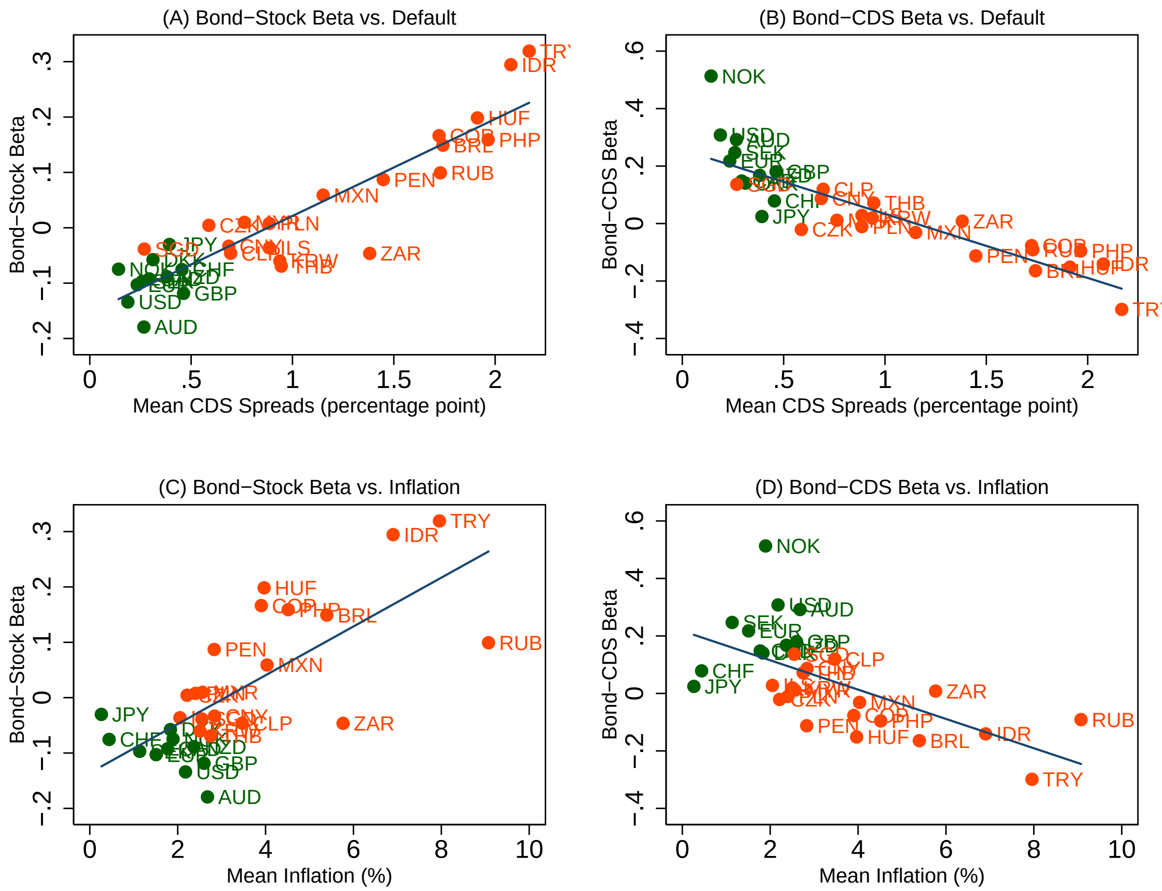


Figure 5: Bond Betas, Default, and Inflation Risk (2005-2014)



Note: Panels A and B plot bond-stock betas and bond-CDS betas against mean CDS spreads, respectively. Panels C and D plot bond-stock betas and bond-CDS betas against mean inflation risks, respectively. Developed markets are denoted by green dots and emerging markets are denoted by red dots. The three-letter currency code is used to label countries.

Table 1: Summary Statistics for Developed and Emerging Markets (2005-2014)

	(1) CDS	(2) π	(3) Survey π	(4) $\beta^{\pi,gdp}$	(5) y	(6) $\beta^{b,s}$	(7) $\beta^{b,cds}$	(8) α^{Nom}
(A) Developed Markets ($N = 11$)								
Mean	0.31	1.70	1.83	0.42	2.62	-0.10	0.21	89.27
S.d.	0.10	0.81	0.64	0.15	1.24	0.04	0.13	11.23
Max	0.46	2.68	2.68	0.71	4.87	-0.03	0.51	100.00
Min	0.14	0.26	0.32	0.24	0.61	-0.18	0.02	65.85
(B) Emerging Markets ($N = 19$)								
Mean	1.26	4.09	3.83	0.21	6.01	0.06	-0.04	63.11
S.d.	0.58	2.05	1.66	0.31	2.91	0.12	0.11	25.58
Max	2.17	9.07	7.90	1.07	12.33	0.32	0.14	100.00
Min	0.27	2.05	2.06	-0.25	1.67	-0.07	-0.30	11.97
(C) Full Sample ($N = 30$)								
Mean	0.91	3.21	3.10	0.28	4.77	0.01	0.05	72.70
S.d.	0.65	2.05	1.68	0.28	2.92	0.13	0.17	24.78
Max	2.17	9.07	7.90	1.07	12.33	0.32	0.51	100.00
Min	0.14	0.26	0.32	-0.24	0.61	-0.18	-0.30	11.97
(D) Mean Difference between Emerging and Developed Markets ($N = 30$)								
Mean Diff.	0.953***	2.391***	2.004***	-0.214**	3.388***	0.160***	-0.248***	-26.16***
	(0.137)	(0.531)	(0.428)	(0.086)	(0.767)	(0.0303)	(0.0466)	(6.791)

Note: This table reports summary statistics for the cross-sectional mean of eight variables for developed and emerging market groups. The variables include (1) CDS, five-year sovereign credit default swap spreads in percentage points, (2) π, realized inflation (%), (3) Survey π, survey inflation (%), (4) $\beta^{\pi,y}$, inflation-output forecast beta, (5) y, five-year nominal LC bond yield, (6) $\beta^{b,s}$, bond-stock beta, (7) $\beta^{b,cds}$, bond-CDS beta, and (8) α^{Nom}, percentage share of nominal debt in total sovereign debt portfolios. Panel (A) reports results for developed markets. Panel (B) reports results for emerging markets. Panel C reports results for the pooled sample. Panel (D) tests the mean difference between developed and emerging markets. Robust standard errors are reported in the parentheses. Significance levels are denoted by *** p<0.01, ** p<0.05, * p<0.1.

Table 2: Cross-Country Correlations Among Default, Inflation and Nominal Bond Risks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	CDS	π	Survey π	$\beta^{\pi,gdp}$	y	$\beta^{b,s}$	$\beta^{b,cds}$	α^{Nom}	First PC
CDS	1.00								
π	0.81	1.00							
Survey π	0.82	0.99	1.00						
$\beta^{\pi,gdp}$	-0.61	-0.63	-0.61	1.00					
y	0.85	0.86	0.86	-0.66	1.00				
$\beta^{b,s}$	0.91	0.72	0.72	-0.61	0.77	1.00			
$\beta^{b,cds}$	-0.87	-0.62	-0.62	0.49	-0.68	-0.84	1.00		
	-0.60	-0.51	-0.49	0.58	-0.67	-0.56	0.56	1.00	
First PC	0.95	0.90	0.90	-0.74	0.93	0.90	-0.83	-0.71	1.00

Note: This table reports cross-country correlations for nine empirical measures across 30 countries during 2005-2014. The variables include (1) CDS, five-year sovereign credit default swap spreads in percentage points, (2) π, realized inflation (%), (3) Survey π, survey inflation (%), (4) $\beta^{\pi,y}$, inflation-output forecast beta, (5) y, five-year nominal LC bond yield, (6) $\beta^{b,s}$, bond-stock beta, (7) $\beta^{b,cds}$, bond-CDS beta, (8) and (9) First PC, the first principal component of the first eight variables.

Appendix

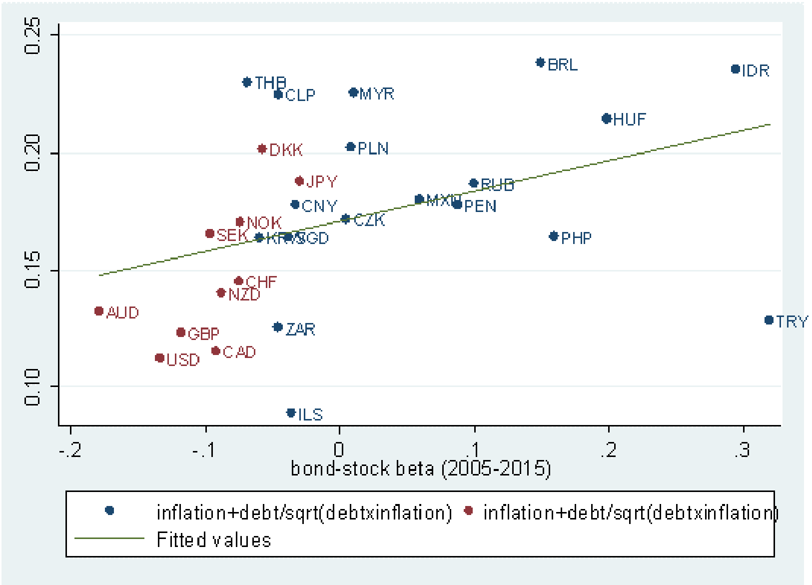
A Evidence from News Counts

So far, we have shown that the share of LC debt issuance lines up with a broad range of macroeconomic, asset pricing, and default risk proxies, that all proxy for monetary policy credibility in the model. While it is comforting that the theory is consistent with a large number of moments, none of these measure monetary policy credibility directly.

Using New York Times articles over the period 1994-2012, we construct the correlation between the key words “debt” and “inflation” for each country as a proxy for inverse inflation credibility. The intuition is that if inflation is solely determined by the central bank and debt is determined by the fiscal authority, these topics should be discussed separately, and the correlation should be low. On the other hand, if inflation and debt are determined by the same central government, we would expect newspaper articles to discuss both at the same time, and the correlation should be high.

We count the number of articles containing both keywords and the country name and divide them by the geometric average of the articles that contain one of the keywords combined with the country name. Consistent with the model, Figure 8 shows that the news count correlation of “debt” and “inflation” is strongly correlated with the bond-stock beta across countries, with a univariate correlation of 40%.

Figure A1: Bond-Stock Betas and News Counts



Note: This figure shows bond-stock betas against the correlation of the keywords “debt” and “inflation” in New York Times articles 1994-2012 from ProQuest Historical Newspapers. We compute the correlation as the number of articles mentioning both “debt” and “inflation” divided by the geometric average of articles that mention either “debt” or “inflation”. We require articles to also mention the country name. The search excludes classified advertisements and stock quotes.

B Model Solution

The cost upon default takes the functional form

$$a - b\frac{1}{D_1^{FC} + D_1^{LC} exp\left(-E_{t-1}\pi_t\right)}. \tag{39}$$

The expected default cost (39) simplifies to

$$\begin{aligned} & a - b\frac{1}{D_1^{FC} + D_1^{LC} exp\left(-E_{t-1}\pi_t\right)}, & (40)\\ = \; & a - \frac{b}{\beta^{-1}V}(1 - P_1), & (41)\\ = \; & \frac{b}{\beta^{-1}V}P_1 + \left(a - \frac{b}{\beta^{-1}V}\right). & (42)\end{aligned}$$

It hence follows that the condition $a \geq \frac{b}{\beta^{-1}V}$ is sufficient to ensure that default costs are always positive.

The expected default cost is the product of (39) and the default probability

$$\begin{aligned} Cost_1 \; &= \; \left(\frac{b}{\beta^{-1}V}P_1 + \left(a - \frac{b}{\beta^{-1}V}\right)\right)P_1, & (43)\\ &= \; \left(\frac{b}{\beta^{-1}V}(\beta^{-1}V\theta^{FC} - (\theta^{FC} - \theta^{LC})s_1) + \left(a - \frac{b}{\beta^{-1}V}\right)\right)(\beta^{-1}V\theta^{FC} - (\theta^{FC} - \theta^{LC})s_1). \end{aligned}$$

Clearly, $Cost_1$ decreases in s_1 for all $s_1 < \beta^{-1}V$. We can then write (up to a constant that does not matter for optimal policy)

$$Cost_1 \; = \; -\frac{c}{2(\alpha^{\pi}\lambda^2 + \alpha^x)}s_1 + \frac{d}{4(\alpha^{\pi}\lambda^2 + \alpha^x)}s_1^2 \tag{44}$$

Here, we can express c and d in terms of the fundamental parameters as

$$\begin{aligned} c \; &= \; 2\left(\alpha^{\pi}\lambda^2 + \alpha^x\right)\left(\theta^{FC} - \theta^{LC}\right)\left(a + 2b\theta^{FC} - \frac{b}{\beta^{-1}V}\right), & (45)\\ d \; &= \; 4\left(\alpha^{\pi}\lambda^2 + \alpha^x\right)\frac{b(\theta^{FC} - \theta^{LC})^2}{\beta^{-1}V}. & (46)\end{aligned}$$

We first solve for no-commitment inflation and output. Without commitment, the government's objective function is to minimize L_2 subject to the PC

$$\pi_2^{nc} \; = \; \lambda x_2^{nc} + u_2. \tag{47}$$

The first-order condition then is

$$2\alpha^x\lambda^{-1}x_2^{nc} + 2\alpha^{\pi}\pi_2^{nc} - s_1 \; = \; 0. \tag{48}$$

It then follows that

$$
\begin{aligned}
\pi_2^{nc} &= \frac{\lambda^2 s_1 + 2\alpha^x u_2}{2(\alpha^\pi \lambda^2 + \alpha^x)}, && (49)\\
x_2^{nc} &= -\frac{\lambda\alpha^\pi}{\alpha^x}\pi_2^{nc} + \frac{\lambda}{2\alpha^x}s_1. && (50)
\end{aligned}
$$

With (49) and (50), the weighted sum of output and inflation deviations in the no-commitment case is (up to an exogenous component)

$$
\alpha^x \left(x_2^{nc}\right)^2 + \alpha^\pi \left(\pi_2^{nc}\right)^2 = \frac{\lambda^2 s_1}{4\left(\alpha^\pi \lambda^2 + \alpha^x\right)}. \tag{51}
$$

Substituting (49) into time-1 inflation expectations gives

$$
E_1\pi_2 = pE_1\pi_2^c + (1-p)\frac{\lambda^2 s_1 + 2\alpha^x \rho_u u_1}{2(\alpha^\pi \lambda^2 + \alpha^x)}. \tag{52}
$$

Let ϕ_1 and ϕ_2 denote the Lagrange multipliers for the time-1 and time-2 PC. The government's problem can be written as the Lagrangian

$$
\begin{aligned}
&\alpha^x x_1^2 + \alpha^\pi \pi_1^2 + \beta p E_1\left[\alpha^x (x_2^c)^2 + \alpha^\pi (\pi_2^c)^2\right] + \beta\frac{\left((1-p)\lambda^2 + d\right)s_1^2 - 2cs_1}{4(\alpha^\pi\lambda^2 + \alpha^x)}\\
&+\phi_1\left[\pi_1 - \lambda x_1 - \beta p E_1 \pi_2^c - \beta(1-p)\frac{\lambda^2 s_1 + 2\alpha^x \rho_u u_1}{2(\alpha^\pi\lambda^2 + \alpha^x)} - u_1\right]\\
&+\beta p \phi_2\left[\pi_2^c - \lambda x_2^c - u_2\right]. && (53)
\end{aligned}
$$

The first-order conditions with respect to x_1 and x_2^c give the shadow cost of relaxing the PC constraint

$$
\begin{aligned}
\phi_1 &= \frac{2\alpha^x}{\lambda}x_1, && (54)\\
\phi_2 &= \frac{2\alpha^x}{\lambda}x_2^c. && (55)
\end{aligned}
$$

The first-order conditions with respect to π_1 and π_2^c give

$$
\begin{aligned}
x_1 &= \frac{-\lambda\alpha^\pi}{\alpha^x}\pi_1, && (56)\\
x_2^c &= \frac{-\lambda\alpha^\pi}{\alpha^x}\left(\pi_2^c + \pi_1\right) && (57)
\end{aligned}
$$

Now, the first-order condition with respect to s_1 is

$$
s_1 = \frac{c}{\lambda^2(1-p)+d} - 2\alpha^\pi \frac{\lambda^2(1-p)}{\lambda^2(1-p)+d}\pi_1, \tag{58}
$$

Substituting (56) into the time-1 PC gives π_1 as a function of $E_1\pi_2$

$$\pi_1 = \frac{\alpha^x\left(\beta E_1\pi_2 + u_1\right)}{\alpha^\pi\lambda^2 + \alpha^x}, \tag{59}$$

$$= \frac{\alpha^x\left[\beta p E_1\pi_2^c + \beta(1-p)\frac{\lambda^2 s_1 + 2\alpha^x\rho_u u_1}{2(\alpha^\pi\lambda^2+\alpha^x)} + u_1\right]}{\alpha^\pi\lambda^2 + \alpha^x} \tag{60}$$

Similarly, we substitute (57) into the time-2 PC to get

$$E_1\pi_2^c = \frac{-\alpha^\pi\lambda^2\pi_1 + \alpha^x\rho_u u_1}{\alpha^\pi\lambda^2 + \alpha^x}. \tag{61}$$

Now, define $w(p)$ and $v(p)$ as functions of p

$$w(p) = \frac{\lambda^2(1-p) + dp}{\lambda^2(1-p) + d}, \tag{62}$$

$$w'(p) > 0, \tag{63}$$

$$v(p) = \frac{\lambda^2(1-p)}{\lambda^2(1-p) + d}, \tag{64}$$

$$v'(p) < 0. \tag{65}$$

Then we can substitute (61) into (60) to obtain

$$\pi_1 = \frac{\beta c\alpha^x}{2}\frac{v}{(\alpha^\pi\lambda^2 + \alpha^x)^2 + \beta\alpha^\pi\alpha^x\lambda^2 w} + \frac{\alpha^x\left((\alpha^x + \alpha^\pi\lambda^2) + \beta\rho_u\alpha^x\right)}{(\alpha^\pi\lambda^2 + \alpha^x)^2 + \beta\alpha^\pi\alpha^x\lambda^2 w}u_1. \tag{66}$$

Since v decreases in p and w increases, it is clear that the average inflation level decreases with credibility. The sensitivity to the cost-push shock also decreases with credibility.

We can now compute the unconditional average LC debt share as

$$E_0 s_1 = \frac{c}{\lambda^2(1-p) + d} - \beta c\alpha^x\alpha^\pi\frac{v^2}{(\alpha^\pi\lambda^2 + \alpha^x)^2 + \beta\alpha^\pi\alpha^x\lambda^2 w}. \tag{67}$$

With $v'(p) < 0$ and $w'(p) > 0$, (67) shows that the unconditional average LC debt share increases in credibility.

Expected inflation is given by

$$E_1\pi_2 = \frac{cv}{2(\alpha^\pi\lambda^2 + \alpha^x)} - \frac{\alpha^\pi\lambda^2 w}{\alpha^\pi\lambda^2 + \alpha^x}\pi_1. \tag{68}$$

The beta of expected inflation with respect to the output gap is hence given by

$$Beta_0\left(E_1\pi_2, x_1\right) = \frac{\alpha^x\lambda w}{\alpha^\pi\lambda^2 + \alpha^x}, \tag{69}$$

which increases in w and hence in p. Note that the timing here is expected inflation in period 2 and the output gap in period 1.

Next, we look at bond and stock returns. Approximate equity-excess returns are

$$\begin{aligned} r_1^e - E_0 r_1^e &= \delta(1-\rho)\left(E_1 - E_0\right)\left(x_1 + \rho x_2\right), & (70)\\ &= \delta(1-\rho)\left(E_1 - E_0\right)\left(\frac{-\lambda\alpha^\pi}{\alpha^x}\pi_1 + \rho x_2\right) & (71)\\ &= \delta(1-\rho)\left(E_1 - E_0\right)\left(\frac{-\lambda\alpha^\pi}{\alpha^x}\pi_1 + \rho\left[p x_2^c + (1-p)x_2^{nc}\right]\right) & (72)\\ &= \delta(1-\rho)\left(E_1 - E_0\right)\left(\frac{-\lambda\alpha^\pi}{\alpha^x}\pi_1 + \rho\left[p\frac{-\lambda\alpha^\pi}{\alpha^x}\left(\pi_2^c + \pi_1\right) + (1-p)x_2^{nc}\right]\right) \end{aligned}$$

Now, we can relate x_2^{nc} to π_2^{nc} and π_t via

$$\begin{aligned} \left(E_1 - E_0\right) x_2^{nc} &= \left(E_1 - E_0\right)\left[\frac{-\lambda\alpha^\pi}{\alpha^x}\pi_2^{nc} + \frac{\lambda}{2\alpha^x}s_1\right], & (73)\\ &= -\frac{\lambda\alpha^\pi}{\alpha^x}\left(E_1 - E_0\right)\left[\pi_2^{nc} - \frac{1}{2\alpha^\pi}s_1\right], & (74)\\ &= -\frac{\lambda\alpha^\pi}{\alpha^x}\left(E_1 - E_0\right)\left(\pi_2^{nc} + \upsilon\pi_1\right) & (75) \end{aligned}$$

Substituting back in, it follows that

$$\begin{aligned} r_1^e - E_0 r_1^e &= -\frac{\lambda\alpha^\pi}{\alpha^x}\delta(1-\rho)\left(E_1 - E_0\right)\left((1+\rho w)\pi_1 + \rho E_1\pi_2\right), & (76)\\ &= -\frac{\lambda\alpha^\pi}{\alpha^x}\delta(1-\rho)\left(1 + \rho w\frac{\alpha^x}{\alpha^\pi\lambda^2 + \alpha^x}\right)\left(E_1 - E_0\right)\pi_1 & (77) \end{aligned}$$

Bond returns are given by

$$\begin{aligned} r_1^{LC} - E_0 r_1^{LC} &= -\left(E_1 - E_0\right)\left(\pi_2 - log(1 - P_2^d)\right), & (78)\\ &\approx -\left(E_1 - E_0\right)\left(\pi_2 - (\theta^{FC} - \theta^{LC})s_1)\right), & (79)\\ &= \left(w\frac{\alpha^\pi\lambda^2}{\alpha^\pi\lambda^2 + \alpha^x} - 2v(\theta^{FC} - \theta^{LC})\alpha^\pi\right)\left(E_1 - E_0\right)\pi_1 \end{aligned}$$

When inflation is unexpectedly high, the government issues more FC debt, which leads to a drop in bond prices.

The beta of LC bond returns with respect to stock returns is then equal to

$$Beta(r_1^{LC}, r_1^e) = \frac{-w\frac{\alpha^\pi\lambda^2}{\alpha^\pi\lambda^2+\alpha^x} + 2v(\theta^{FC} - \theta^{LC})\alpha^\pi}{\frac{\lambda\alpha^\pi}{\alpha^x}\delta(1-\rho)\left(1 + \rho w\frac{\alpha^x}{\alpha^\pi\lambda^2+\alpha^x}\right)} \qquad (80)$$

Now,

$$\frac{2v(\theta^{FC}-\theta^{LC})\alpha^{\pi}}{\frac{\lambda\alpha^{\pi}}{\alpha^{x}}\delta(1-\rho)\left(1+\rho w\frac{\alpha^{x}}{\alpha^{\pi}\lambda^{2}+\alpha^{x}}\right)} \tag{81}$$

decreases in p, because the numerator is positive and decreases in p and the denominator is positive and increases in p. Since higher credibility means less time-variation in credit risk, the credit component of LC bond betas decreases with credibility.

In addition

$$\frac{-w\frac{\alpha^{\pi}\lambda^{2}}{\alpha^{\pi}\lambda^{2}+\alpha^{x}}}{\frac{\lambda\alpha^{\pi}}{\alpha^{x}}\delta(1-\rho)\left(1+\rho w\frac{\alpha^{x}}{\alpha^{\pi}\lambda^{2}+\alpha^{x}}\right)} \tag{82}$$

decreases in w and hence in p. With higher credibility, the central bank engages in more forward guidance, driving down the expected inflation component of LC bond betas. Taken together, LC bond betas with respect to the stock market are predicted to decrease in credibility.

The beta of LC bond returns with respect to default risk is given by

$$\frac{-w\frac{\alpha^{\pi}\lambda^{2}}{\alpha^{\pi}\lambda^{2}+\alpha^{x}}}{2(\theta^{FC}-\theta^{LC})\alpha^{\pi}v}-1. \tag{83}$$

The default risk beta of LC bonds hence decreases in p.

We can also compute the beta of long-run average inflation $E_1(\pi_1+\pi_2)$ with respect to the expected output gap over the same time period $E_1(x_1+x_2)$. This is given by

$$Beta_0\left(E_1\left(\pi_1+\pi_2\right),E_1\left(x_1+x_2\right)\right) = \frac{\alpha^{x}}{\lambda\alpha^{\pi}}\frac{\alpha^{\pi}\lambda^{2}w-(\alpha^{\pi}\lambda^{2}+\alpha^{x})}{\alpha^{x}w+(\alpha^{\pi}\lambda^{2}+\alpha^{x})}, \tag{84}$$

which increases in w and hence in p.

Now, the beta of expected period 2 inflation with respect to expected period 2 output is

$$Beta_0\left(E_1\pi_2,E_2x_2\right) = \frac{-w\frac{\alpha^{\pi}\lambda^{2}}{\alpha^{\pi}\lambda^{2}+\alpha^{x}}}{\frac{-\lambda\alpha^{\pi}}{\alpha^{x}}w\frac{\alpha^{x}}{\alpha^{\pi}\lambda^{2}+\alpha^{x}}}, \tag{85}$$

$$= \lambda. \tag{86}$$

Now, the different expressions (69), (84) and (86) show that the timing convention of inflation and output expectations is quite important. The beta of inflation expectations with respect to the current output gap is an important driver of how bond betas change with credibility.

B.1 Model Implications

1. The level of inflation decreases in credibility.

2. The LC debt share increases in credibility.

3. The LC debt share varies procyclically. Said differently, the government issues more FC debt during recessions.

4. Default risk varies countercyclically. Alternatively, CDS spreads should be higher during recessions.

5. The inflation expectations-output beta increases with credibility.

6. The LC bond-stock beta decreases with credibility.

7. The LC bond beta-default risk beta decreases with credibility.

C An Alternative Model with Exogenous Inflation and Output Dynamics

This appendix section considers an alternative model of government debt portfolio choice. The purpose of this model is to derive the implications for LC and FC debt issuance, when countries face exogenous differences in inflation and output dynamics. For instance, some countries might be more exposed to commodity shocks, which could give rise to stagflationary recessions.

The model in this section implies that for countries with countercyclical inflation, LC debt service is lowest during recessions. Such countries should therefore prefer LC debt to minimize default costs. However, empirically we see that countercyclical inflation expectations go along with FC borrowing. We therefore conclude that the choice between FC and LC debt is not primarily a function of country exposures to inflation and business cycle shocks.

C.1 Model Setup

The government again borrows a fixed real V in period 1. Let D^{FC} and D^{LC} denote the face values of the two types of debt outstanding and q^{FC} and q^{LC} the corresponding prices per unit of face value. Log real output $x = log(X)$ and log inflation $\pi = log(\Pi)$ in period 2 are jointly conditionally lognormal with

$$\begin{bmatrix} x \\ \pi \end{bmatrix} \sim N\left(\begin{bmatrix} \mu_x \\ \mu_p \end{bmatrix}, \underbrace{\begin{bmatrix} \sigma_x^2 & \sigma_{xp} \\ \sigma_{xp} & \sigma_p^2 \end{bmatrix}}_{\Sigma}\right). \tag{87}$$

Sovereign default is costly and a fraction $(1-\theta)$ of total real output is lost in default. In case of default, bond holders receive nothing, and all remaining output is consumed within the country.

The government defaults when the real face value of debt exceeds the cost from defaulting, similarly to Merton (1974). The government defaults if and only if

$$(1-\theta)exp(x) \quad < \quad D^{FC} + D^{LC}exp(-\pi). \tag{88}$$

Condition (88) shows that the government chooses to default when output is low or the real face value of debt is high. Since the real face value of LC debt decreases with inflation, the government is less likely to default when inflation is high.

C.2 Bond Prices

Investors are risk neutral and discount future cash flows at a constant discount factor β, just like the government. FC and LC bond prices are given by

$$q^{FC} = \beta \left(1 - E\left[I_{(1-\theta)exp(x)-D^{LC}exp(-\pi)-D^{FC}<0}\right]\right), \tag{89}$$
$$q^{LC} = \beta E\left[exp(-\pi)\left(1 - I_{(1-\theta)exp(x)-D^{LC}exp(-\pi)-D^{FC}<0}\right)\right]. \tag{90}$$

Here I denotes an indicator function that equals one if the argument is true and zero otherwise.

C.3 Government Objective Function

The government maximizes expected output net of debt repayment costs, discounted at a constant discount factor β. The government's problem hence is

$$\max_{D^{FC},D^{LC}} \beta E\left[max\left(exp(x) - D^{FC} - D^{LC}exp(-\pi), \theta exp(x)\right)\right], \tag{91}$$

subject to the constraint

$$V = q^{FC}D^{FC} + q^{LC}D^{LC}. \tag{92}$$

Substituting (89), (90), and (92) into the objective function (91)

$$\underbrace{exp\left(\mu_x + \frac{1}{2}\sigma_x^2\right)}_{\text{Exp. Output}} - \underbrace{(1-\theta)E\left(exp(x)I_{(1-\theta)exp(x)-D^{LC}exp(-\pi)-D^{FC}<0}\right)}_{\text{Exp. Default Cost}} - \underbrace{\beta^{-1}V}_{\text{Exp. Bond Cash Flows}}. \tag{93}$$

Since the government and investors are risk-neutral, expected bond cash flows equal $\beta^{-1}V$. Total expected output available for consumption is expected output less default costs. Expression (93) shows that the government's objective is equivalent to minimizing expected default costs.

C.4 Approximate Analytic Solution

Next, we obtain an intuitive approximate solution, based on approximating a linear combination of lognormal distributions as lognormal (Campbell and Viceira, 2002). We find that this approximation works well for reasonable parameter values. Countries in our sample have 5-year CDS spreads of less than 5%. We therefore derive an approximate solution for the empirically relevant case with small default probabilities. For a default probability close to zero, the budget constraint is approximated by

$$V \quad = \quad \beta D^{FC} + \beta exp\left(-\mu_p + \frac{1}{2}\sigma_p^2\right) D^{LC}. \tag{94}$$

Next, we use Girsanov's theorem to rewrite the expected default cost as

$$\begin{aligned} & (1-\theta)E\left(exp(x)I_{(1-\theta)exp(x)-D^{LC}exp(-\pi)-D^{FC}<0}\right) && (95)\\ = \; & (1-\theta)exp(\mu_x + \frac{1}{2}\sigma_x^2) \\ & \times P\left[(1-\theta)exp(\sigma_x^2 + x) - D^{LC}exp(-\sigma_{xp} - \pi) - D^{FC} < 0\right]. && (96)\end{aligned}$$

But now with (94)

$$\begin{aligned} & E[(1-\theta)exp(\sigma_x^2 + x) - D^{LC}exp(-\sigma_{xp} - \pi) - D^{FC} && (97)\\ = \; & (1-\theta)exp(\frac{3}{2}\sigma_x^2 + \mu_x) - D^{LC}exp(-\mu_p + \frac{1}{2}\sigma_p^2)\left[exp(-\sigma_{xp}) - 1\right] - \beta^{-1}V. && (98)\end{aligned}$$

When $\sigma_{xp} \approx 0$, the expectation (98) is close to independent of D^{LC} and hence the government's debt portfolio choice.

Letting $\tilde{x} = x - \mu_x$ and $\tilde{\pi} = \pi - \mu_\pi$, we use a loglinear approximation to obtain the variance

$$\begin{aligned} & Var\left[(1-\theta)exp(\sigma_x^2 + x) - D^{LC}exp(-\sigma_{xp} - \pi) - D^{FC}\right] && (99)\\ \approx \; & Var\left[(1-\theta)exp(\mu_x + \sigma_x^2)\tilde{x} + D^{LC}exp(-\mu_p - \sigma_{xp})\tilde{\pi}\right] && (100)\\ = \; & (1-\theta)^2 exp(\mu_x + \sigma_x^2)^2\sigma_x^2 + (D^{LC})^2 exp(-\mu_p - \sigma_{xp})^2\sigma_p^2 && (101)\\ & +2(1-\theta)D^{LC}exp(\mu_x + \sigma_x^2)exp(-\mu_p - \sigma_{xp})\sigma_{xp}. && (102)\end{aligned}$$

If the random variable $(1-\theta)exp(\sigma_x^2 + x) - D^{LC}exp(-\sigma_{xp} - \pi) - D^{FC}$ is close to normal, the probability of a negative realization depends only on its mean and variance. Its mean is approximately independent of D^{LC}, so the government's portfolio choice problem reduces to minimizing the variance of the difference between default costs and debt payouts (102). Together with the assumption that local currency debt issuance cannot be negative, this gives the solution

$$D^{LC} \quad \approx \quad max\left(-\frac{\sigma_{xp}}{\sigma_p^2}(1-\theta)exp(\mu_x + \sigma_x^2 + \mu_p + \sigma_{xp}), 0\right). \tag{103}$$

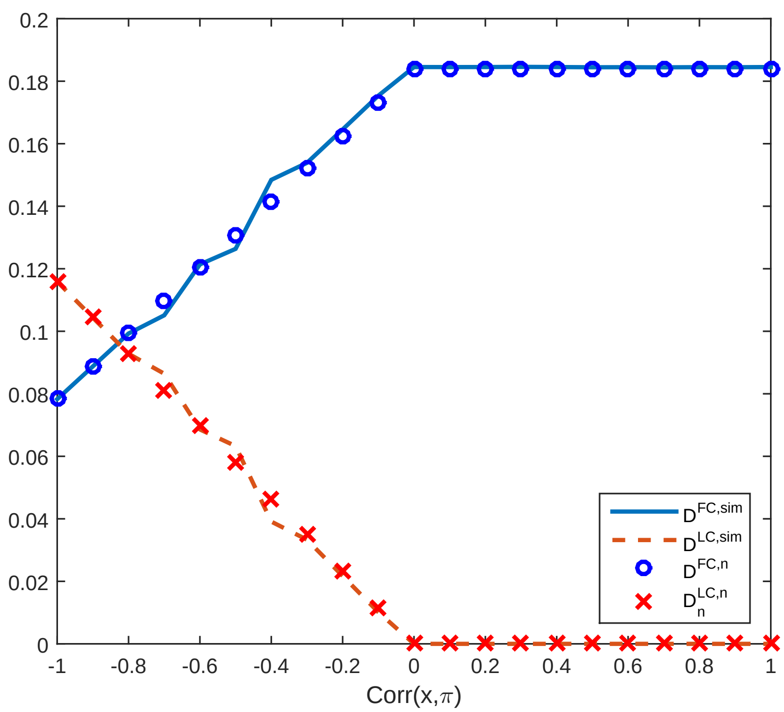
The approximate solution (103) clearly decreases in the output-inflation covariance. The intuition is that when the output-inflation covariance is positive borrowing in local currency increases debt repayments exactly when output is low. Since the government is faced with high real debt repayments and low output and tax revenues at the same time, it is likely to default. Seeking to minimize expected default costs ex-ante a government with a positive inflation-output covariance therefore borrows in foreign currency in this model.

C.5 Numerical Evaluation of Analytic Solution

We obtained the approximate solution (103) as a loglinear approximation. We now compare it to an exact simulated solution for a particular set of parameter values. We use $\theta = 0.8$, $\sigma_x = 0.05$, $\sigma_p = 0.1$, $\mu_x = 0.05$, $\mu_p = 0.10$, $\beta = 0.98$, and $V = 0.18$. We plot the optimal debt portfolio against the output-inflation correlation, which we vary from -1 to 1. The simulated solution uses 100,000 draws for x and π and minimizes the objective function over $10,000$ randomly chosen values for D^{FC} and D^{LC}.

Figure A1 plots the solutions for D^{FC} and D^{LC} against the output-inflation correlation $\rho_{xp} = \frac{\sigma_{xp}}{\sigma_x \sigma_p}$. Up to simulation noise, the simulated and normal solutions are indistinguishable. We can see that the face value of local currency debt decreases and the face value of foreign currency debt increases with ρ_{xp}.

Figure C2: Optimal Debt Portfolio in Alternative Model



This figure plots the analytic approximate solution (103) for the face value of local currency debt, $D^{LC,n}$, and the face value of foreign currency debt, $D^{FC,n}$ against the output-inflation correlation. The corresponding simulated solutions are denoted by $D^{LC,sim}$ and $D^{FC,sim}$. All parameter values are as listed in section C.5.