Sovereign Debt Disclosure[1]

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Abstract

This paper studies debt and default dynamics under alternative disclosure arrangements in a sovereign default model. The government can access both observable and hidden debt. We show that when debt is not fully disclosed, the government does not internalize the full effects of hidden debt choices on bond prices, thereby reducing the cost of holding hidden debt. We find that switching to a full disclosure regime shifts the portfolio from hidden to observable debt, exacerbating the debt dilution problem. Thus, contrary to conventional wisdom, this switch generates welfare losses.

Keywords: Hidden debt, Debt disclosure, Sovereign debt, Sovereign default, Sovereign-to-sovereign lending

JEL Codes: E31, F34, F45.

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1 Introduction

Government borrowing is mainly composed of sovereign bonds, official loans from other sovereigns, and funds from multilateral institutions. The terms and conditions of sovereign bonds and multilateral funds are publicly disclosed, however sovereign-to-sovereign arrangements are less transparent (Gelpern et al., 2021). While members of the Paris Club, a group of major creditor countries, publicly disclose information on their lending, non-members do not. This paper studies sovereign debt and default dynamics under alternative disclosure arrangements.

In the past several decades, non-Paris Club lending has increased substantially in international financial markets, particularly in the financing of emerging and developing economies (see Appendix A.1 and Horn et al., 2021).[1] As the terms and conditions of this funding are not revealed in detail, it has recently provoked a heated debate regarding the role of disclosure practices and transparency in the debt and default dynamics of sovereign borrowing. While the impact of financial disclosure on corporate borrowing is well-documented, the dynamics of sovereign debt and default under varying disclosure arrangements have not been as thoroughly explored. This gap in the literature persists despite ongoing policy debates that emphasize the benefits of transparency and disclosure practices.[2] Sovereign debt differs from private borrowing in that it has a limited enforcement of repayment. The consequences of this lack of enforcement coupled with limited commitment have ramifications for debt default mechanisms, risk sharing, and other macroeconomic dynamics, all of which have been widely examined in the quantitative sovereign debt and default literature (Aguiar and Amador, 2014; Aguiar et al., 2016). To our knowledge there is no formal analysis of full disclosure and nondisclosure in a sovereign debt environment with these properties. Therefore we aim to fill this gap.

We develop a quantitative model of sovereign debt and default where the sovereign has access to two sources of borrowing: one representing the non-contingent debt borrowing from international bond investors, and the other reflecting a non-defaultable a sovereign-to-sovereign collateralized loan (which we will label S2S) from a non-Paris club lender. Later on we relax this assumption and allow S2S debt to be defaultable as well. We assume that the level of non-contingent debt is public information, however information on the choice of S2S debt comes with a lag and the current S2S debt choice is only visi-

[1] According to Horn et al. (2021), China's lending (a large non-Paris club creditor) increased from near zero in 1998 to 1.6 trillion USD (1.5% of global GDP) as of 2018. Similarly, as of 2017, the proportion of developing and emerging countries receiving loans from China rose to more than 80% compared to below 5% in the 1950s.

[2] See Leuz and Wysocki (2016) and De George et al. (2016) for recent surveys of literature on the role of financial disclosure in corporate sector.

ble to the corresponding lender and sovereign.[3] The remainder of investors, on the other hand, do not observe the choice of S2S debt, but form expectations on it using information on the other actions of the sovereign. This information asymmetry in the model aims to capture the lack of disclosure, a major concern for debt sustainability in low income countries as noted in IMF (2020).

The rest of the model assumptions rely on the standard quantitative sovereign default models of Eaton and Gersovitz (1981) and Arellano (2008), and government borrowing mimics realistic long-term debt contracts as in Hatchondo and Martinez (2009) and Chatterjee and Eyigungor (2012). We also incorporate a Nash-bargaining game between international lenders and the borrower into our analysis, in the spirit of Yue (2010), as the renegotiation protocol may be affected depending on whether the S2S debt is observable. This small open economy is populated by a continuum of households, a benevolent government, and a continuum of risk-neutral bond investors. In each period, the sovereign chooses the amount of borrowing from each market, after which it receives an aggregate income shock and decides to repay or default on its defaultable debt. If the government chooses to default, it is excluded from the international capital markets for a random and finite number of periods. International investors price the bond based on the risk of sovereign default reflecting the level of debt, income shock and (exogenous) consumption process of foreign investors. The cost of non-Paris Club borrowing follows the consumption process of foreign investors, introducing time variation in the term structure of default-free S2S bonds. We calibrate the model parameters to reflect the economic statistics of Bolivia, a lower-middle-income country with substantial amounts of both non-contingent and non-Paris Club debt, as well as China's consumption process, given its role as the primary holder of S2S debt.

The rise of China as a significant player in international capital markets, characterized by its unique lending practices, holds substantial importance. In our paper, we take initial steps to unravel the underlying reasons for the existence of hidden debt. Hidden debt involves two key entities: the borrower and China. Regarding the borrower side, our contribution encompasses a quantitative model challenging the conventional belief by demonstrating that hidden debt can indeed enhance overall welfare. Concerning China, our theory deliberately sidesteps the complexities of modeling trade and political fric-

[3] We assume that the choice of S2S debt level from non-Paris Club lenders comes with a lag since they are not reported officially. With that said that, partial information regarding this type of lending is still accessible with research. For example, Gelpern et al. (2021) studied 100 such debt contracts between China's (a large non-Paris Club member creditor) state-owned institutions and foreign governments to document the terms and conditions in this type of lending. However, the information– which is still partial because only a limited number of contracts are documented–is disclosed with lags.

tions associated with hidden debt. Instead, we posit that, as argued by Gelpern et al. (2021), China opts not to disclose its lending to secure a senior lender status, granting it priority access to non-contingent assets upon default.[4] We also document that China's hidden lending behavior to the rest of the world constitutes only 1.2% of its GDP, with less than 0.02% for Bolivia. Consequently, defaults or fluctuations in the market value of this debt do not impact S2S debt holders consumption. Thus, we model the S2S debt holders preferences using the recursive utility model proposed by Epstein and Zin (1989) and Weil (1989). With this, we provide a model in which we answer the question "why there is hidden debt."

We solve two versions of our model: a nondisclosure (ND) economy, where the level of S2S debt choice is only visible to the corresponding lender and sovereign, and a full disclosure (FD) economy, where all information is public. We show that the presence of a distortion favoring S2S debt in the ND economy. In the presence of informational frictions, bond prices do not depend on the choice of the S2S debt, which reduces the cost of holding the S2S debt. We show that this channel generates a higher S2S debt and lower non-contingent debt in the nondisclosure economy compared to the full disclosure economy. So, a shift from the ND economy to the FD economy results in a shift from S2S debt to the non-contingent debt. In the short-run, as S2S debt decreases, bond prices improve, overall debt level increases, allowing for a higher net revenue from debt issuance as well as a higher consumption level for the sovereign.

The transition between the two economies reveal nonlinear dynamics. The portfolio shift from S2S debt to non-contingent debt between ND and FD economies occurs mostly in the first several years of the transition after which the FD economy gradually converges to the new ergodic state. As the portfolio shifts from S2S debt, which is non-defaultable towards non-contingent debt, which is defaultable, the default rate increases. Higher non-contingent debt also exacerbates the debt dilution problem, and the sovereign faces higher spreads for the bonds, which amplifies the defaults. Quantitatively, these competing channels lead to an initial drop in welfare during the transition, followed by a continuous decline throughout the remainder of the period. To characterize the welfare loss, we also redo our analysis with one-period debt. The intuition is as follows: there are two

[4] Gelpern et al. (2021) review 100 debt contracts between Chinese stat-owned entities and government borrowers in 24 developing economies. The evidence suggests that Chinese state-owned institutions use formal and informal contract arrangements to protect their investments and gain seniority. For example, they use collateral terms in the forms of liens, escrow and special accounts much more extensively in comparison to the commercial and official lenders. Moreover, all contracts in the sample require the borrower to exclude the debt from any multilateral restructuring process. Bredenkamp et al. (2019) call these arrangements as "restructuring-resistant contracts" and discuss the *de facto seniority* of non-Paris Club lenders (China the largest by far) in the sovereign debt markets.

main sources of inefficiencies in quantitative default models with long-term debt: (i) default and (ii) debt dilution, which is also referred to as time inconsistency in the literature. When we repeat the analysis with one-period debt, where debt dilution is not a concern and sequential decisions become optimal from a time-zero perspective, we demonstrate that welfare losses are eliminated and, in fact, welfare gains arise from moving to full disclosure. This confirms our intuition that the debt dilution problem, exacerbated by the government's higher debt issuance in the FD economy with long-term debt, results in a welfare loss at the time of the switch.

We conduct a series of robustness analyses, which include introducing signaling motives, varying the duration, exclusion, bargaining, discount factor, and S2S bond holders' risk aversion parameters. Additionally, we test scenarios where endogenous recovery is turned off and constant recovery is assumed. We also relax the assumption that S2S debt is non-defaultable. Our qualitative results remain consistent across these alternative parametrizations and specifications.

This paper adjoins the literatures on sovereign debt and financial disclosure. While a large body of work studies the sovereign debt and default dynamics based on the model of Eaton and Gersovitz (1981), only a limited number of papers do so in the context of asymmetric information.[5] Among those, Cole et al. (1995), Sandleris (2008), and Phan (2017) study sovereign default models under which repayments function as a signalling mechanism that affect default costs when lenders and the sovereign have asymmetric information regarding the fundamentals of the country. Guler et al. (2022) examine sovereign debt sustainability in an asymmetric information setup between lenders and the borrower with one period assets. Horn et al. (2024) studies the effects of hidden debt on sovereign debt dynamics, but they model the hidden debt as an exogenous process and ignore the strategic interactions between the hidden debt and market debt. Perez (2017) explores the optimal maturity of sovereign debt, and shows that maturities display a negative correlation with spreads under asymmetric information structure. D'Erasmo (2008) and Amador and Phelan (2021) examine the role of government reputation in sovereign default dynamics using asymmetric information regarding government's willingness to repay. Dovis and Kirpalani (2020) and Dovis and Kirpalani (2022), on the other hand, study the role of government reputation as a bail out authority, to explain interest rate dynamics and effectiveness of fiscal rules. Bai and Zhang (2012) show that information flows plays a key role in explaining the heterogeneity in duration of renegotiation across countries and loan types. Using bid-level data and a sovereign debt model featuring in-

[5]See Aguiar and Amador (2014) and Aguiar et al. (2016) for recent surveys of literature on the quantitative sovereign default models.

formation asymmetries across bidders, Cole et al. (2022) illustrates that the differences in bid acceptance rates across large and small bidders are explained by their ability to access information. We add to this body of work by proposing an explicit sovereign default model with two assets (a standard sovereign bond and a hidden sovereign-to-sovereign loan) and a long-term borrowing structure. Our model differs from others in that it has an asymmetric information structure between lenders and borrowers in the debt dimension, which reflects current public borrowing patterns in nations with lack of reporting practices.[6]

Our full disclosure economy is also related to a growing quantitative literature that decomposes different types of sovereign debt. Boz (2011), Fink and Scholl (2016), Hatchondo et al. (2017), Önder (2022) and Mimir and Önder (2024) examine concessional loan like instruments within a quantitative default framework. Arellano and Barreto (2024) also investigate the business cycle dynamics of concessional sovereign debt using a partial default framework.

The debt dilution problem lies at the core of our welfare results. Numerous novel studies have examined this issue. A significant reference for our study is Bizer and DeMarzo (1992), which explores a scenario where a borrower can borrow sequentially from multiple lenders, but the initial lenders cannot condition their loan offers based on the amounts borrowed from subsequent lenders. Similar to our findings, their study demonstrates that debt dilution can lead to equilibria with higher debt levels and increased interest rates, driven by higher default probabilities. Other notable studies highlighting the impact of debt dilution in sovereign debt markets include Hatchondo et al. (2016) and Chatterjee and Eyigungor (2015).

A large strand of literature studies the relation between the corporate cost of capital and financial disclosure. Among others, Verrecchia (1983), Diamond and Verrecchia (1991), Easley and O'hara (2004), and Barth et al. (2013) show that reducing information asymmetries can lower a firm's cost of capital by increasing the demand from investors. Duarte et al. (2008), Chen et al. (2010), Lambert et al. (2012), and Hermalin and Weisbach (2012), on the other hand, claim that the relation between asymmetric information and the cost of capital depends on factors such as the degree of competition in capital markets and firm size using cross sectional variance across listed firms. In contrast with the exist-

[6] Another strand of literature related to our work studies informational frictions in credit default models. Among others, Guler (2015) shows that improvements in information technologies that mitigate the asymmetric information between lenders and borrowers explain the dynamics in mortgage credit markets in the United States in the early 2000s. Narajabad (2012) studies the role of informational frictions in the increase of default rates in the non-contingent credit markets. Chatterjee et al. (2020) studies the role of informational frictions in the adaptation and usefulness of credit scores for the credit markets.

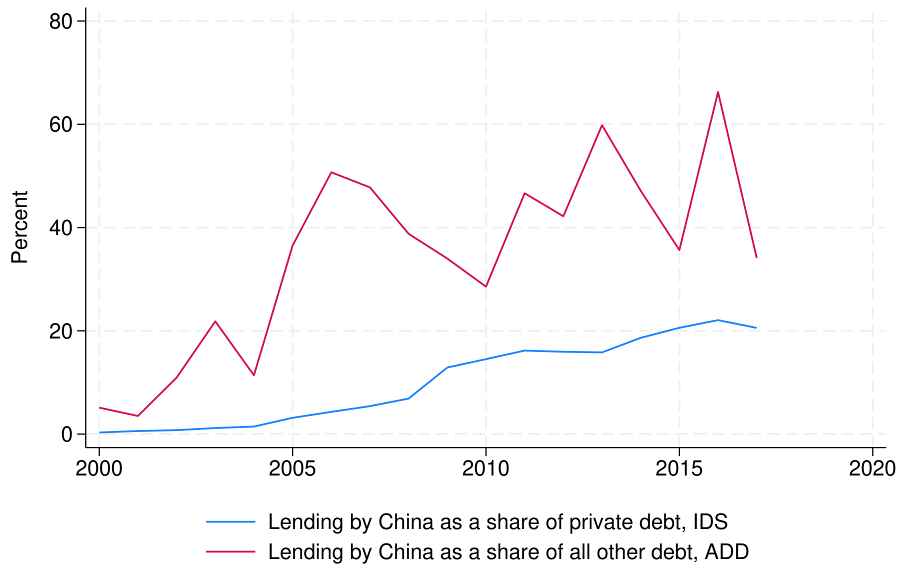

Figure 1: ADD is African Debt Database and it covers a sample of 44 African countries. IDS is International Debt Statistics, and it covers a global sample of low- and middle-income countries that report public and publicly guaranteed external debt to the World Bank's Debtor Reporting System. Data source: Mihalyi and Trebesch (2022) and World Bank.

ing studies, we focus on the role of information on sovereign debt and default dynamics and contribute to the existing literature on financial disclosure.

The remainder of the paper is organized as follows. In the next section, we provide institutional background on China's hidden lending practices. Following this, we present a quantitative model in Section 3, elaborate on our calibration in Section 4, present our results in Section 5, and conclude in Section Section 6.

2 Institutional Background

In this section, we briefly revisit the recent evidence on the rising role of China in international capital markets and focus on China as a lender.[7] Figure 1 shows that Chinese cross-border lending has emerged in early 2000s, and increased to roughly one fifth of the lending by private creditors. This is even more striking in the case of African countries where this share has reached to about 60 percent by 2017. While the total debt to private creditors exceed debt to China on aggregate, cross-country sample reveals that debt to China is even much larger than debt to private creditors in many countries across the

[7] See, for instance, Horn et al. (2019) and Mihalyi and Trebesch (2022) for detailed empirical evidence on China's rising cross-border lending.

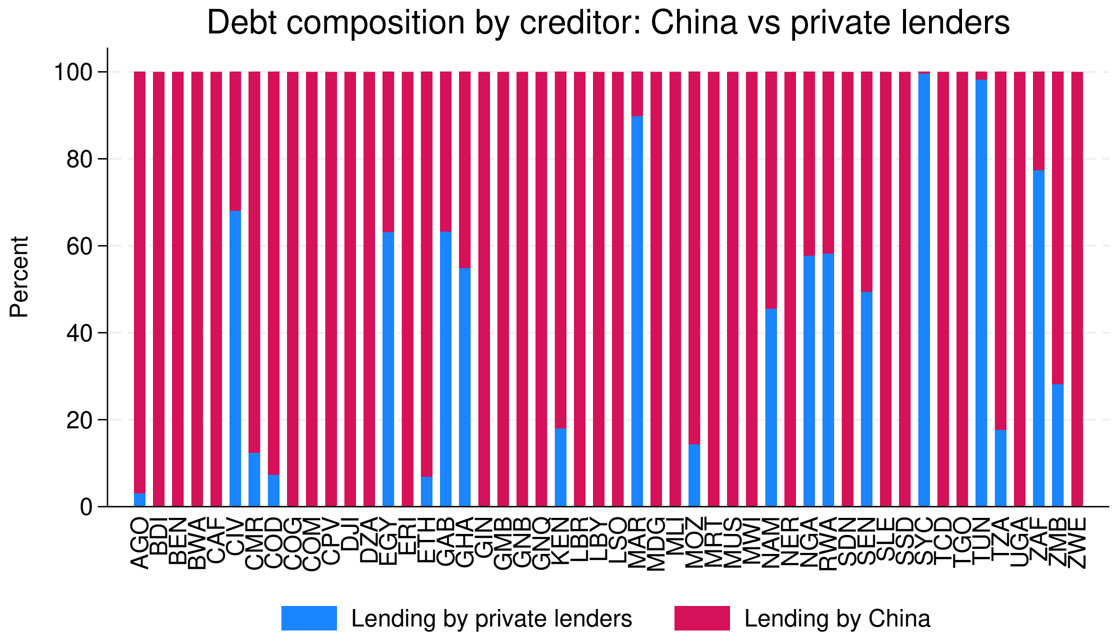

Figure 2: The data shows the relative share of debt to China and debt to private lenders in the African Debt Database between 2000 and 2017. Debt to China is mostly composed of lending by Chinese state-owned banks. Private creditors are bondholders. Data source: Mihalyi and Trebesch (2022) and World Bank.

sample (Figure 2). Overall, these figures illustrate the significant role of China's lending in sovereign borrowing of developing economies.

In order to explore the potential correlates of the interest rate on Chinese loans, we use cross-country panel data of Chinese lending to countries reporting to the Debt Reporting System of the World Bank. More specifically, we estimate various versions of the following equation:

$$1/(1+R_{it}) = \alpha + \beta c_t + \delta y_{it} + \gamma d_{it} + \boldsymbol{Year_t^{FE}} + \boldsymbol{Country_i^{FE}} + \epsilon_{it}, \tag{1}$$

where, R_{it} denotes the average interest rate on new lending by China at time t to country i, and c_t represents consumption growth of China at time t, in current USD. The term y_{it} denote the business cycle of borrower country i at time t measured as log quadratically de-trended GDP in constant local currency units. The next term d_{it} reflects the external debt to GDP ratio of the debtor country i at time t. Finally, $\boldsymbol{Year_t^{FE}}$ and $\boldsymbol{Country_i^{FE}}$ control for the time and country fixed effects, respectively.

Table 1 presents the estimated coefficients of equation (1). The reciprocal of gross interest rate in Chinese loans to developing countries is negatively correlated with China's

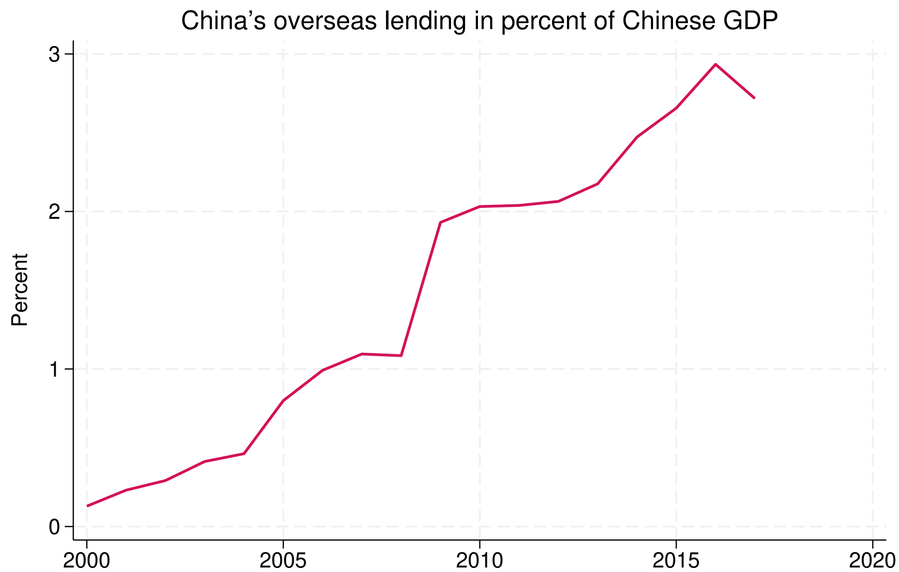

Figure 3: The chart plots data from International Debt Statistics which covers a global sample of low- and middle-income countries that report public and publicly guaranteed external debt to the World Bank's Debtor Reporting System. Data source: World Bank.

own consumption growth measured in the same currency with its lending (USD), and this is robust to various empirical specifications. The estimated coefficients of other potential determinants such as borrower's business cycle and external debt are either statistically or economically insignificant on the lending rate in Chinese loans.

These empirical findings highlight the emergence of China as a lender in the sovereign debt markets and the significant influence of Chinas economic conditions on its lending rates. To understand debt and default dynamics in this environment, we now turn to a quantitative model that features both observable and hidden sovereign debt.

3 Quantitative Model

In this section, we present a quantitative model of sovereign default following Eaton and Gersovitz (1981) and Arellano (2008) augmented by a long-term defaultable bond as in Hatchondo and Martinez (2009) and Chatterjee and Eyigungor (2012). We also incorporate another non-defaultable, S2S long-term borrowing option while incorporating a Nash-bargaining game between the borrower and international lenders if a default occurs. To study the effects of informational frictions we solve two versions of this model. First economy (full disclosure-FD) augments a standard small open economy with an alternative borrowing option for the government in addition to bond investors featured in

Table 1: Interest rate on China's international lending

1/ Gross interest rate on new lending	(1)	(2)	(3)	(4)	(5)
China consumption growth	**-0.206*****	**-0.209*****	**-0.202*****	**-0.211*****	**-0.202*****
	(0.049)	(0.048)	(0.045)	(0.053)	(0.048)
Debtor business cycle	-0.004			-0.004*	
	(0.002)			(0.002)	
Debtor's external debt/GDP	0.002***	0.002***		0.002***	
	(0.001)	(0.001)		(0.001)	
Constant	1.008***	1.009***	1.009***	1.009***	1.009***
	(0.004)	(0.004)	(0.003)	(0.004)	(0.003)
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	No	No
Observations	3,720	3,769	3,982	3,720	3,982
R-squared	0.056	0.056	0.058	0.055	0.053
Number of countries	92	94	94	94	94

Notes: Standard errors in parentheses. *** and ** reflect p<0.01 and p<0.05, respectively. Table reports the estimated coefficients of different versions of equation (1). Average interest rate on new lending by China is as reported in the Debt Reporting System of the World Bank. Sample covers 1970 to 2017. Business cycle of the debtor country is measured as log quadratically de-trended GDP measured in constant local currency units. Columns (1) to (3) reflect estimated coefficients from panel data fixed effect regressions where, in (1) borrower's business cycle and debt/GDP ratios are controlled along with China's business cycle, and year and country fixed effects, in (2) borrower's business cycle is excluded, and in (3) borrower's debt/GDP is also excluded. Columns (4) and (5) show estimates coefficients from cross-country OLS regressions, with and without additional controls (borrower's business cycle and debt/GDP ratio), respectively. Data set covers a global sample of low- and middle-income countries that report public and publicly guaranteed external debt to the World Bank's Debtor Reporting System. Data sources: World Bank's International Debt Statistics, Horn et al. (2021).

the existing models. The additional lender extends a non-defaultable collateralized loan to the borrower. The sovereign is assumed to borrow from the two international lenders as appropriate and to make a repayment/default decision on the bonds. In this economy, we assume that all information is public and symmetric across all agents.

The second model (nondisclosure–ND) differs from the FD economy in its information setup between the borrower and the lenders. In this version, the total debt is assumed to be perfectly observable to the sovereign only. The international bond investors, on the other hand, observe the income shocks, current non-contingent debt and current S2S (hidden) debt of the government precisely, and forms expectation over the government's hidden debt choice to be paid next period based on the information revealed at each period.[8] Each model is described in detail in the following subsections.

[8]The lending rate of the S2S debt follows the consumption process of foreign investors, introducing time variation in the term structure of default-free S2S bonds. Therefore the information setup does not affect the behavior of the lender of the S2S debt.

3.1 Full Disclosure Economy

We study a small open economy model inhabited by a continuum of infinitely lived, identical households and a sovereign government. The domestic economy's output is subject to endowment shocks under incomplete markets. The sovereign maximizes the utility of the representative household and has the option to default on its non-contingent debt, should it find it optimal. The S2S debt is assumed to be non-defaultable.[9]

Households and endowments. A large number of identical consumers have preferences over flows of consumption defined as

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t), \tag{2}$$

where $0 < \beta < 1$ is the subjective discount factor (identical across individuals) and E is the mathematical expectation operator. The utility function takes the constant relative risk aversion (CRRA) form,

$$u\left(c\right) = \frac{c^{1-\sigma}}{1-\sigma}. \tag{3}$$

The function $u(.)$ is continuous and strictly concave in consumption and satisfies the Inada condition, $\lim_{c \to 0^+} u'\left(c\right) = \infty$. The parameter $\sigma > 0$ represents the level of constant relative risk aversion.

The small open economy is endowed with a single tradable good, which follows an exogenous stochastic process

$$\log y_{t+1} = \left(1-\rho\right)\bar{y} + \rho \log y_t + \varepsilon_{t+1} \tag{4}$$

where $\bar{y}$ is the unconditional mean of the log endowment, $|\rho| < 1$ is the autocorrelation of the endowment and ε is zero mean and constant variance Gaussian innovations.

Debt contracts. The sovereign has options to issue a non-state contingent asset in international bond markets (b) and to borrow from a S2S debt market (b_c) if it has access to. The defaultable debt market is modeled to mimic the structure of the standard long-term international bonds, and is assumed to deliver an infinite stream of coupons that decreases at a constant rate, δ. As such, its level evolves as follows:

$$b_{t+1} = \left(1-\delta\right) b_t + l_t,$$

[9] The FD economy environment is similar to Hatchondo et al. (2017) and Önder (2022).

where b_t is the stock of existing debt at period t, and l_t is the number of bonds issued at period t.

Equilibrium price of the defaultable bond is determined under a competitive international capital market with a large number of lenders. The investors discount future by risk free rate, r, are assumed to be risk neutral, and constrained by a zero-expected-profit condition.

Non-defaultable debt's repayment structure is similar to the defaultable bond, that is:

$$b_{c,t+1} = (1-\delta)\, b_{c,t} + l_{c,t},$$

where b_c stands for the level of S2S debt, and the law of motion follows a similar structure described for the non-contingent debt. We impose an upper bound on the S2S debt, $\bar{b}_c$, to have a well-defined problem for the sovereign.

Repayment. In each period, after observing the income shock, the sovereign decides whether to repay its debt or default on it. Conditional on repaying debt, consumption becomes

$$c_t = y_t + q_t\left(b_{c,t+1}, b_{t+1}, y_t, g_t\right)\left(b_{t+1} - (1-\delta)\, b_t\right) - \kappa b_t$$

$$+ q_{c,t}\left(b_{c,t+1} - (1-\delta_c) b_{c,t}\right) - \kappa_c b_{c,t}. \tag{5}$$

Prices $q_{c,t}$ and q_t denote the asset prices of S2S and non-state contingent debt, respectively, and κ and κ_c denote periodic coupon payments.

Default. When the government chooses to fully repudiate by defaulting on its debt obligations, it loses access to both foreign capital markets (both for non-state contingent and S2S debt) for a stochastic number of periods into the future. We assume that the government cannot default on the S2S debt. In autarky periods, households would be able to consume only the endowment of the economy, which reflects a potential resource penalty of default. The sovereign is also subject to other default costs represented by $\phi\left(y_t\right)$, which depends on the realization of the endowment. The sovereign also has to make periodic payment for the S2S debt in the default state.

$$c_t = y_t - \phi\left(y_t\right) - \kappa_c b_t^c. \tag{6}$$

We assume that $\phi(.)$ takes a quadratic form, $\phi\left(y\right) = \max\left\{0,\ d_0 y + d_1 y^2\right\}$ with $d_1 > 0$ to avoid default in high income realizations as discussed by Arellano (2008) and Chatterjee and Eyigungor (2012). We calibrate these parameters in order to match the moments of debt statistics such as debt-to-GDP ratios and sovereign spreads. Temporary exclusion from debt markets suggests that re-entry occurs only with probability $0 < \psi < 1$. Upon re-entry, we assume a Nash-bargaining game between the government and the holders of defaulted non-contingent debt. Notice that upon default, the sovereign cannot issue any additional debt and continues to make coupon payments on the S2S debt.

International lenders. There are two types of lenders: international lenders that invest on non-contingent debt and S2S debt investors who only holds S2S debt. International investors price loans made to the sovereign in both assets, taking decision rules for default d, the borrowing portfolio b_c, b and macroeconomic fundamentals of the small open economy y, as given. International lenders seek a no-arbitrage condition over investing in risk-free debt versus purchasing the non-contingent sovereign bond. The pricing kernel of foreign lenders who purchase non-state contingent debt implies risk neutrality with

$$m_{t,t+1} = \frac{1}{1+r^*}. \tag{7}$$

That is, non-state contingent debt investors should be indifferent between earning the international risk-free rate and purchasing non-state contingent debt.

In models of long-term debt with positive recovery, the government may be incentivized to issue debt at the highest possible level just before defaulting, potentially generating consumption hikes (Hatchondo et al., 2016; Hatchondo et al., 2023). To mitigate this, following Hatchondo et al. (2016) and Hatchondo et al. (2023), we assume that the borrower is not allowed to issue bonds at a price lower than $\underline{q}$. However, the asset price can still fall below $\underline{q}$ in the secondary market. The value we assign to $\underline{q}$ prevents consumption sprees before defaults and does not bind in the simulations.

For holders of S2S debt, their pricing kernel is derived from their optimization problem. This kernel reflects that (i) the debt issued by the Bolivian government represents a small fraction of the wealth of the bondholder, in this case China. In fact, the S2S debt that China holds from Bolivia is less than 0.02% of China's GDP. As a result, defaults or fluctuations in the market value of this debt do not affect the consumption of S2S debt holders; and (ii) Bolivia's and China's shocks are uncorrelated. This is also supported by our estimates in Table 1, which show that the correlation is not economically meaningful. This approach is similar to studies (e.g., Piazzesi and Schneider, 2007; Hatchondo et al., 2016) that examine the price behavior of large open economies, especially US government bonds. Following Hatchondo et al., 2016 notation, the growth rate of bondholders' consumption (denoted by g^*) follows an AR(1) process, namely,

$$log(g_t^*) = (1-\rho^*)\mu_g^* + \rho^* log(g_{t-1}^*) + \varepsilon_t^* \tag{8}$$

where μ_g^* denotes the mean consumption growth, $|\rho^*| < 1$, and $\varepsilon_t \sim N(0, \sigma_{\epsilon^*}^2)$.

The S2S debt holders preferences are captured by the recursive utility model initially proposed by Epstein and Zin (1989) and Weil (1989). This model allows for a constant coefficient of relative risk aversion that can differ from the reciprocal of the intertemporal elasticity of substitution. The bondholders' preferences can be described as follows:

$$\begin{aligned} log[V^*(c_t^*, g_t^*)] &= (1-\beta^*) log(c_t^*) \\ &\quad + \frac{\beta^*}{1-\gamma^*} log\{E[V^*(c_{t+1}^*, g_{t+1}^*)^{1-\gamma^*} | g_t^*]\}, \end{aligned}$$

where c_t^* represents the S2S debt holders consumption in period t, β^* is their discount factor, and γ^* is their coefficient of relative risk aversion. This specification assumes a unitary elasticity of intertemporal substitution. Given that preferences are homothetic, the function V^* depends linearly on c^*, leading to

$$log[V^*(c_t^*, g_t^*)] = log(c_t^*) + log(\tilde{V}^*(g_t^*))$$

with

$$\begin{aligned} log(\tilde{V}^*(g_t^*)) = \frac{\rho^*\beta^*}{1-\rho^*\beta^*} log(g_t^*) + \frac{(1-\rho^*)\beta^*}{(1-\beta^*)(1-\rho^*\beta^*)}\mu_g^* \\ + \frac{1}{2}\frac{(1-\gamma^*)\beta^*}{(1-\beta^*)(1-\rho^*\beta^*)^2}\sigma_{\epsilon^*}^2. \end{aligned}$$

The stochastic discount factor for S2S debt holders is given by:

$$M(g_t^*, g_{t+1}^*) = \beta^* \frac{(g_{t+1}^*)^{-\gamma^*} \tilde{V}^*(g_{t+1}^*)^{1-\gamma^*}}{E[[g_{t+1}^* \tilde{V}^*(g_{t+1}^*)]^{1-\gamma^*} | g_t^*]} \tag{9}$$

where $M(g_t^*, g_{t+1}^*)$ is the value bondholders assign to a payment of one unit of the good when their consumption growth rate in the next period is g_{t+1}^* and their current consumption growth rate is g_t^*. The price of the S2S debt, $q_{c,t}$, would then equal the S2S debt holders stochastic discount factor. This specification is aligned with our estimations in Table 1, where we present that holders of S2S debt require lower (higher) interest rates on new lending if their income is growing (falling).

3.1.1 Recursive Representation

Here, we describe the maximization problem of the sovereign in recursive representation. Let $s \equiv (y, g^*)$ denote the vector of exogenous states. Each period, upon observing s, sovereign chooses between repayment and default:

$$V(b, b^c, s) = \max\left\{V^r(b, b_c, s), V^d(b, b_c, s)\right\} \tag{10}$$

so that if $V^r(b, b^c, s) > V^d(b, b^c, s)$, the decision rule for default takes the value $\hat{d}(b, b_c, s) = 0$. Otherwise, it is equal to $\hat{d}(b, b^c, s) = 1$.

Upon deciding to repay the existing debt, the sovereign chooses the levels of new S2S borrowing, b_c', non-state contingent debt, b', and consumption. The value function of repayment decision, V^r, maximizes the expected utility of repaying its debt given the state variables, b_c, b, and s. Accordingly, the value of repayment decision satisfies the following:

$$V^r(b, b_c, s) = \max_{b_c' \leq \bar{b}_c, b', c \geq 0} \left\{u(c) + \beta \mathbb{E}_{s'|s}\left[V\left(b', b_c', s'\right)\right]\right\}, \tag{11}$$

subject to

$$c = y + M(g^*, g^{*\prime})\left(b_c' - (1-\delta_c)\, b_c\right) - \kappa_c b_c$$
$$+ q\left(b', b_c', s\right)\left(b' - (1-\delta)b\right) - \kappa b$$
$$\text{and} \quad q\left(b', b_c', s\right) \geq \underline{q} \quad \text{whenever} \quad b' - (1-\delta)\, b > 0.$$

In the government's budget constraint, $M(g^*, g^{*\prime})$ and q represent the prices of S2S debt and non-state contingent debt, respectively. The parameters κ and κ_c determine the level of coupon payments of the corresponding debts in each period.

Let $(1-\psi)$ denote the probability of a sovereign's exclusion from the international capital markets, the value of default decision (on the non-state contingent debt) is defined by the following function:

$$\begin{aligned} V^d(b, b_c, s) = {} & u\left(y - \phi(y) - \kappa b_c\right) \\ & + \beta \mathbb{E}_{s'|s}\left[\psi\, V^r\left(\hat{\alpha}(b, b_c, s')b, (1-\kappa_c)b_c, s'\right)\right. \\ & \left. + (1-\psi)\, V^d\left(b, (1-\kappa_c)b_c, s'\right)\right], \end{aligned} \tag{12}$$

where the equilibrium recovery rate, $\hat{\alpha}$, solves the Nash bargaining problem between the lenders and the sovereign. The surplus of the sovereign is the difference between the value of gaining access to the bond markets, represented by $V^r(\alpha b, (1-\kappa_c)b_c, s')$, and the value of staying in default state, represented by $V^d(b, b_c, s)$. The surplus of the lenders is assumed to be the difference between the market value of bonds outside of default and in default. The market value of a debt portfolio outside of the default region is given by

$$MV^r(b,b_c,s) \quad = \quad \kappa b + (1-\delta)bq(\hat{b}(b,b_c,s),\hat{b}_c(b,b_c,s),s)$$

and

$$MV^d(b,b_c,s) \quad = \quad bq^D(b,b_c,s),$$

defines the market value of debt in default. The price of non-contingent bonds follows

$$q\left(b',b_c',s\right) \quad = \quad \frac{\mathbb{E}_{s'|s}\left\{\left[(1-d')\left[(1-\delta)q\left(b'',b_c'',s'\right)+\kappa\right]+d'q_d\left(b',b_c',s'\right)\right]\right\}}{1+r^*}, \tag{13}$$

where

$$\begin{aligned} &q_d\left(b',b_c',s\right) = \\ &\mathbb{E}_{s'|s}\left\{\left[\psi\,\hat{\alpha}(b',b_c',s')\left(\left[\kappa+(1-\delta)q\left(\hat{b}\left(\hat{\alpha}b',(1-\kappa_c)b_c',s'\right),\hat{b_c}\left(\hat{\alpha}b',(1-\kappa_c)b_c',s'\right),s'\right)\right]\right)\right.\right. \\ &\left.\left.+(1-\psi)q_d\left(b',(1-\kappa_c)b_c',s'\right)\right]\right\}, \end{aligned} \tag{14}$$

is the price functional in default.

Given these definitions, we can define the problem characterizing the equilibrium recovery rate as:

$$\begin{aligned} \hat{\alpha}(b,b_c,s) = \arg\max_{\alpha\in[0,1]} &\left\{\left[V^r(\alpha b,(1-\kappa_c)b_c,s)-V^d(b,b_c,s)\right]^{\phi}\right. \\ &\left.\left[MV^r(\alpha b,(1-\kappa_c)b_c,s)-MV^d(b,(1-\kappa_c)b_c,s)\right]^{1-\phi}\right\}. \end{aligned} \tag{15}$$

where ϕ representing the bargaining power of the sovereign.

The solution to the government's problem yields a default decision rule $\hat{d}\,(b,b_c,s) \in \{0,1\}$, two borrowing rules that determine the debt portfolio $\hat{b}^c(b,b^c,s)$ and $\hat{b}(b,b^c,s)$. In equilibrium, defined in Section 3.1.2, lenders use these decision rules to solve the Nash-bargaining game and price non-state contingent debt contracts. Specifically, equilibrium pricing schedule q solve the following functional equations evaluated at equilibrium decision rules for borrowings and default: with equation (13) denoting the pricing functional of non-contingent asset and equation (14) standing for the pricing functional of non-contingent bonds that are in default in the current period.

According to Equation (13), risk neutral lenders optimize the arbitrage over an outside investment option that would gain a gross real return of 1+r^* when buying sovereign bonds. If lenders hold the bonds and the government serves its debt the following year, they will obtain a coupon payment, κ, and the option to sell the remaining portion of the bonds at market price. If the government defaults in the following year, lenders can only exchange the defaulted bonds at the price q_d.

Equation (14) describes the price of bond upon the government's default decision, q_d. It is determined by the current period's non-contingent debt and S2S debt levels, the output growth of domestic government, the S2S debt holders' consumption growth, as well as the probability of access to international capital markets upon default decision, ψ. The government repays its debt with a haircut, $(1 - \hat{\alpha})$ which is determined through Nash bargaining between the government and international lenders. During exclusion, non-state contingent debt is assumed to grow at the world interest rate, r^*.

3.1.2 Equilibrium

Lenders observe the sovereign's limited commitment to repayment, ruling out reputation building via signaling. As Krusell and Smith (2003) show, lack of commitment to future policies might cause indeterminacy of Markov equilibria in the infinite horizon. Therefore, we focus on Markov Perfect Equilibria (MPE) which arise as the limits of finite horizon economies wherein the government's equilibrium default, borrowing decisions depend only on payoff relevant state variables.

Definition *A Markov Perfect Equilibrium is characterized by value functions V, V^r, V^d, bond pricing functionals q, q_d and policy rules for default $\hat{d}$ and borrowing, recovery rate, consumption $\hat{b}_c, \hat{b}, \hat{\alpha}, \hat{c}$ such that*

1. *Given bond pricing functionals $\{q, q_d\}$, non-contingent debt recovery rate $\hat{\alpha}$ government policy rules $\{\hat{d}, \hat{b}_c, \hat{b}, \hat{c}\}$ solve the utility maximization problem defined in equations (10), (11) and (12).*

2. *Given government policy rules $\{\hat{d}, \hat{c}, \hat{b}_c, \hat{b}\}$, the pricing functionals $\{q, q_d\}$ and the recovery rate $\hat{\alpha}$ satisfy conditions (13), (14) and (16).*

3.2 Nondisclosure Economy

This section describes the model environment featuring the nondisclosure setup between the lenders and the borrower. In this model, international lenders observe the income shock once it is revealed and the current as well as the history of the non-state contingent borrowing decisions of the sovereign. However, the level of the sovereign's S2S debt is not directly observable to the lenders and becomes public in the next period. We focus on Markov Perfect Equilibrium. Although lenders cannot observe the S2S debt choice, they form expectation over the evolution of it conditional on sovereign's current period observables. We also assume that the initial starting debt level of the sovereign is arbitrary and common information. This assumption together with the fact that the history of borrowing decisions for state non-contingent debt allow the lenders to infer the current debt position of the sovereign for the S2S debt. However, lenders cannot observe the *choice* of the S2S debt for the following period, which constitutes the main difference of the ND economy from the FD economy.

3.2.1 Recursive Representation

The sovereign's optimal borrowing and repayment decisions adjust to the nondisclosure setup in which lenders offer a pricing kernel based on its limited information on the sovereign. Lenders' new pricing function (q^{ND}) feeds into sovereign's budget constraint, resulting in the following optimization problem:

$$
\begin{aligned}
& V^r\left(b, b_c, s\right)=\max_{b^{c\prime},\, b^{\prime},\, c}\ \left\{u\left(c\right)+\beta\, \mathbb{E}_{s^{\prime}\mid y}\left[V\left(b^{\prime}, b_c^{\prime}, s^{\prime}\right)\right]\right\}, \qquad (16)\\
& \text{subject to}\\
& c=y+M(g^*, g^{*\prime})\left(b_c^{\prime}-(1-\delta)\, b_c\right)-\kappa_c b_c\\
& \quad+q^{ND}(b^{\prime}, b, b_c, s)\left(b^{\prime}-(1-\delta) b\right)-\kappa b\\
& \text{and}\quad b_c^{\prime}-(1-\delta)\, b_c \geq 0 \ \text{ whenever } \ b^{\prime}-(1-\delta) b>0.
\end{aligned}
$$

The main difference in the ND economy relies on the pricing function of the non-state contingent debt (q^{ND}). In the FD economy, q depends on all state variables (b', b_c', s) of the sovereign. But in the ND economy, it depends on the observables (b', b, b_c, s)[10]. Accordingly, q^{ND} is defined as:

$$
q^{ND}\left(b^{\prime}, b, b_c, s\right)=q\left(b^{\prime}, \hat{b}_c^{\ell}(b, b_c, s), s\right) \qquad (17)
$$

[10] As we discussed earlier, although the lenders cannot observe b_c directly, given that the initial S2S debt and all history of state non-contingent debt levels are observable, the lenders can infer the current S2S debt level in a Markov Perfect Equilibrium.

where $\hat{b}_c^l$ is the lender's belief about the evolution of the S2S debt of the sovereign and q is defined as in equation (13).

Off-equilibrium path beliefs: The role that off-equilibrium beliefs may play in our framework deserves attention as these beliefs may play a significant role in driving results. Our belief structure implicitly assumes that the lenders believe the government will pick the same b_c' conditional on observing b, b_c y and b', i.e. the lender's belief function is assumed to be independent of the choice of future non-state contingent debt.[11]

3.2.2 Equilibrium

The formal definition of our equilibrium concept is provided below.

Definition *A Nondisclosure Markov Perfect Equilibrium is characterized by value functions V, V^r, V^d, bond pricing functions q^{ND}, q, q_d, beliefs $\hat{b}_c^l$, and policy rules for default $\hat{d}$, borrowing $\hat{b}_c, \hat{b}$, the recovery rate $\hat{\alpha}$ and consumption $\hat{c}$ such that*

1. *Given the beliefs, $\hat{b}_c^l$, and the bond pricing schedules $\{q^{ND}, q_c, q\}$, government policy rules $\{\hat{d}, \hat{b}_c, \hat{b}\}$, the recovery rate $\hat{\alpha}$ solve the utility maximization problem defined in equations (16) and (12).*

2. *Given the beliefs, $\hat{b}_c^l$, and government policy rules $\{\hat{d}, \hat{c}, \hat{b}_c, \hat{b}\}$, the pricing functions $\{q^{ND}, q, q_d\}$, the recovery rate $\hat{\alpha}$ satisfy conditions (17), (13), (14) and (16).*

3. *The function $\hat{b}_c^l$ is consistent with government's borrowing rule $\hat{b}_c$.*

What makes the ND economy different from the FD economy is the independence of the pricing function for the non-state contingent debt on the choice of S2S debt. In the FD economy, q depends on the choice of S2S debt b_c' in addition to the choice of non-state contingent debt, b', and level of endowment, y. However, in the ND economy, since S2S debt is not observable, the pricing function, q^{ND}, does not depend on the *choice* of the S2S debt, b_c'. This means that the effects of the choice of the S2S debt on the price of the non-state contingent debt are not internalized by the sovereign.

To extend on the intuition, consider the following counterfactual. Suppose that we are in the FD economy and the government suddenly switches to the ND economy, and let's assume that in the first period after the switch, lenders would still offer a menu of equilibrium prices obtained in the FD economy. Now, however, as the government

[11] One can think of different belief structures, which are also dependent on the choice of non-state contingent debt. However, this requires strong assumptions on coordination of lenders on the same belief structure. Thus, we believe our belief structure is simplistic and a natural starting point for the analysis of nondisclosure regime in a parsimonious way in the dynamic setting.

searches for the optimal hidden debt choice, it may obtain a different optimal allocation as the government receives identical price offers for every hidden debt choice for a given observable set of states it is experimenting with. That is, for any choice with b_c' by the government, given the quintuple (b', b, b_c, s), lenders offer the same price q^{ND} because they cannot observe the government's hidden debt choice. Thus, they condition their price according to their beliefs, which is in this case the hidden debt level observed in the FD economy given a quintuple. In the next period, lenders update their beliefs about the government's hidden debt choice and eventually allocations converge to their new equilibrium.

The analysis of the Euler equations also reveal this difference. Let $q_c = M(g^*, g^{*\prime})$, in the FD economy, the Euler equation for the S2S debt is as follows:

$$u'(c)\left(q_c + q_2\left(b', b_c', s\right)\left(b' - (1-\delta)\, b\right)\right) = \beta\, \mathbb{E}_{s'|s}\left\{(1-\hat{d})u'\left(c'\right)\left[(1-\delta_c)\, q_c + \kappa_c\right] + \hat{d} V_2^d(b', b_c', s')\right\},$$

whereas in the ND economy the Euler equation becomes:

$$u'(c)\, q_c = \beta\, \mathbb{E}_{s'|s}\left\{(1-\hat{d})u'\left(c'\right)\left[(1-\delta_c)\, q_c + \kappa_c - q_3^{ND}(b'', b', b_c', s')\left(b'' - (1-\delta) b'\right)\right] + \hat{d} V_2^d(b', b_c', s')\right\}$$

where q_i denotes the derivative of the q function with respect to the i^{th} argument.

Two opposing effects emerge from the comparison of these Euler equations. On the one hand, in the ND economy, the Euler equation does not include the term $[u'(c)\, q_2\left(b', b_c', s\right) (b' - (1-\delta)b)]$, which captures the effect of a S2S debt on the current utility through the effect of the collateral debt on the *current* price of the non-state contingent debt, captured by $q_2\left(b', b_c', s\right)$. This term is negative since higher S2S debt increases the likelihood of default in the future periods. The absence of this term in the Euler equation of the ND economy encourages the sovereign to increase the S2S borrowing and decrease the non-state contingent debt in the ND economy. This effect generates a portfolio shift in the ND economy from the non-state contingent debt towards the S2S debt.

The second effect is the presence of the effect of S2S debt on the *future* price of the non-state contingent debt, which is captured by the term on the right hand side of the Euler equation: $u'(c')\left[q_3^{ND}(b'', b', b_c', s')\left(b'' - (1-\delta) b'\right)\right]$. This effect increases the marginal cost of the S2S debt and decreases the marginal cost of non-state contingent debt, and discourages the sovereign from increasing the S2S debt and encourages the issuance of non-state contingent debt. The net effect depends on the magnitude of these two effects, which we explore in the quantitative section.

A few aspects of the pricing function deserve additional discussion. Lenders can perfectly anticipate the amount of hidden debt the country holds for the next period, b_c', after

Table 2: Parameters

	Symbol	Value	Description
External parameters			
Discount factor	β	0.92	Literature
Risk aversion of households	γ	2	Literature
Income autocorrelation coefficient	ρ	0.85	Estimated
Standard deviation of innovations	σ_ϵ	0.024	Estimated
Risk-free rate	r	0.04	Literature
Probability of re-entry after default	ψ	0.5	Literature
Upper bound of S2S debt	$\bar{b}_c$	0.12	Data
Debt duration	$\delta = \delta_c$	0.2845	3 yrs
Price cap for new debt issuance	$\underline{q}$	0.45	Literature
Sovereign's bargaining power	ϕ	0.93	recovery rate = 67%
S2S debt holders' risk aversion	γ^*	59	Literature
S2S debt holders' consumption auto correlation	ρ^*	0.614	China private consumption
S2S debt holders' standard deviation of consumption innovations	σ^*_ϵ	0.017	China private consumption
S2S debt holders' mean consumption growth	μ^*_g	$-0.5(\sigma^*_\epsilon)^2$	China private consumption
Internally Calibrated Parameters			
Income cost of defaulting	d_0	-1.20	Mean debt/GDP = 30.23%
Income cost of defaulting	d_1	1.3128	Mean EMBI spread = 2.57%
S2S debt holders' discount factor	β^*	0.91	Hidden debt/GDP = 8.2%

having observed (b', b, b_c, s) equilibrium quintuples. Yet, this does not mean that the equilibrium prices in the ND economy coincide with the ones in the FD economy. In the FD economy, the lender can observe the choice of the S2S debt, and the bond prices offered in equilibrium reflect this fact. However, if lenders offer the equilibrium prices of the FD economy in the ND economy, the sovereign might find it optimal to deviate from the portfolio choice in the FD economy since any such deviation in the S2S debt will not be observable in the FD economy, hence, the lenders cannot change the price accordingly as they do in the FD economy. This main distinction allows the sovereign to issue more S2S debt in the ND economy compared to the FD economy.

4 Calibration

This section presents a selection of parameters for the model economies and discusses simulation results. The moments of the model data target the business cycle and debt statistics characteristics of Bolivia. In the baseline scenario, we assume the nondisclosure (ND) setup between the borrower and lenders. This is consistent with the fact that a large number of countries have both transparent and hidden components in their total debt portfolio, as documented in Horn et al. (2021).

Table 2 summarizes the parameters used in the baseline calibration. A period in the model economy is set to one year. Accordingly, the discount factor parameter β is set to 0.92, a common value for studies of sovereign default with annual models. We provide robustness checks for alternative values of the discount factor β in Section A.3.1. The representative agent in the sovereign economy is assumed to have a constant relative risk aversion γ of 2, in line with the quantitative business cycle and sovereign default studies (e.g. García-Cicco et al., 2010). We set $\underline{q} = 0.45$ to eliminate consumption spree before defaults and it never binds in simulations.

Parameters of the income process, described in equation (4), are estimated using annual real GDP data for Bolivia covering the period from 1980 to 2017. The estimation employs HP filtering with a smoothing parameter of 100, utilizing data from FRED. Autocorrelation coefficient of AR(1) income process, ρ is estimated 0.85, and the standard deviation of the i.i.d shocks to income, σ_ϵ, is estimated 0.024. We set $\delta = \delta_c = 0.2845$ which yields an average duration of 3 years which is in line with the range of 3 to 5 years for emerging markets documented in literature. It follows that coupon payments $\kappa = \kappa_c = \frac{r^*+\delta}{1+r}$. In Subsection A.3.1, we also have a robustness check when the duration of the debt is set to be around 6 years.

The probability of re-entry after default, ψ, is set to 0.5 to match two years of exclusion from international capital markets upon default, which is within the range of exclusion values used in the sovereign default literature. Subsection A.3.1 experiments with alternative values of the exclusion parameter for robustness purposes. In order to obtain a haircut value of 37 percent $(1-\alpha)$ in simulations, we set the bargaining power of the sovereign $\phi = 0.93$. 37 percent haircut rate is in the range of estimates provided by Meyer et al. (2022) and is used in quantitative default studies (Hatchondo et al., 2016; Hatchondo et al., 2023). Subsection A.3.2 provides a battery of robustness tests with respect to the government's bargaining power parameter.

The maximum S2S debt the sovereign can borrow, $\bar{b}_c$, is set to 0.12 motivated by the fact that it is the maximum hidden debt reported in Horn et al. (2021) for Bolivia. According to this source, the average Chinese lending to Bolivia amounted to 8.2 percent of its GDP between 2012 and 2017. Additionally, the external debt to gross national income ratio, based on World Bank data, was 30.23 percent, and the average EMBI spread for the same period was 2.56 percent.

To estimate the parameters governing the pricing kernel for S2S debt holders, we utilize China's real final consumption expenditure as a proxy for bondholders' consumption growth.[12] We use equation (8) to estimate the parameters ρ^*, μ_g^*, and σ_ϵ^* utilizing China's real final consumption expenditure data that spans the period from 1980 to 2019.

[12] Piazzesi and Schneider (2007) estimated this using U.S. personal consumption expenditures in non-durable goods and services from National Income and Product Accounts data. Since equivalent data for China is unavailable, we use real final consumption expenditure instead.

Table 3: Long-run Statistical Moments

	Data	ND	FD
Targeted moments			
Non-contingent debt/GDP (%)	30.23	31.39	34.42
S2S (hidden) debt/GDP (%)	8.20	9.15	6.56
Mean spread, $E(R_s)$(%)	2.48	2.00	2.26
Duration, years	3	3.07	3.05
Recovery rate (%)	63	62.98	62.28
Non-targeted moments			
Default rate (%)	5	4.98	5.95
$\sigma(c)$ / $\sigma(y)$	1.22	1.19	1.13
$\sigma(tb)/\sigma(y)$	0.51	0.68	0.55
$\rho(c, y)$	0.81	0.99	0.99

Notes: ND and FD stand for nondisclosure and full disclosure, respectively.

The bondholders' discount factor, β^*, is calibrated to ensure that Bolivia's mean annual hidden debt-to-GDP ratio aligns with observed data. For the bondholders' relative risk aversion coefficient, γ^*, we adopt the value suggested by Piazzesi and Schneider (2007) and Hatchondo et al. (2016). In a representative agent framework, a high risk aversion parameter for bondholders is required to account for the (nominal) term premium in the U.S., given the relatively low volatility of aggregate consumption growth. Subsection A.3.3 demonstrates that varying the bondholders' risk aversion parameter does not significantly impact the model dynamics.

Finally, the parameters capturing the income cost of defaulting, d_0 and d_1 are calibrated jointly to match the mean debt to GDP ratio, and mean EMBI spread over the sample period.

5 Quantitative Results

This section presents the simulation results of our quantitative models. We discuss the implications of nondisclosure (between lenders and government) for public debt, borrowing costs, default rates, and business cycle properties.

5.1 Key Statistics: Model vs Data

Table 3 compares the moments of the ergodic distributions of ND and FD economies with the empirical counterparts. Top and bottom panels present the targeted and non-targeted data moments, respectively.

The benchmark model returns a non-state contingent debt to GDP ratio slightly above 31.4 percent which is roughly equal to the long-term average of external debt to GDP ratio in Bolivia. Hidden debt to GDP ratio is estimated around 9.15 percent of GDP, which is slightly above the share of hidden debt in total external debt, approximated by Horn et al. (2021). The sovereign spread averages 200 basis points, which roughly matches its empirical counterpart. Debt duration is calculated using Macaulay definition, in which the duration is computed as the weighted average maturity of future cash flows, which corresponds to periodic coupon payments, κ in our model.[13] Parameter δ is calibrated to 0.2845 which returns an average duration of 3 years for non-state contingent debt in simulations. Recovery rate matches well its targeted moment of 63%.

The bottom panel of Table 3 shows the performance of the model in matching non-targeted data moments. Data moments for consumption and the trade balance are obtained from World Bank data spanning 1980 to 2017, with HP filtering applied using a smoothing parameter of 100. Simulations generate a high relative consumption volatility ($\sigma(c)$ / $\sigma(y)$), a countercyclical trade balance ($\sigma(tb)/\sigma(y)$), and a highly procyclical consumption ($\rho(c, y)$), in line with data and the benchmark studies (Aguiar and Gopinath, 2007; Arellano, 2008). Overall, the model does a fairly good job in matching the empirical moments.

5.2 Long-run Comparison of FD and ND Economies

The main driver of changes across two economies is the change in the price of non-state contingent debt the sovereign faces. In the FD economy, the sovereign faces bond prices conditional on not only income and non-state contingent borrowing level but also S2S borrowing level. However, in the ND economy, bond prices do not directly depend on the S2S debt level. They indirectly affect bond prices through its effects on the beliefs about the evolution of the S2S debt.

Figure 4 plots the equilibrium bond price (q) against the state variables in the FD and ND economies. The figure on the left illustrates the bond price of the non-contingent debt as a function of current period non-contingent debt whereas the panel on the right plots the bond price as a function of current period S2S debt both in FD and ND economies.

[13] More precisely, D = $\frac{1+i}{i+\delta}$ where i is the periodic yield an investor would earn if the bond is held to maturity with no default and it satisfies $q = \sum_{j=1}^{\infty} \frac{\kappa(1-\delta)^{j-1}}{(1+i)^j}$. The sovereign spread r_s is computed as the difference between yield i and the risk free rate r. Annualized spread reported in the table is computed as $1 + r_s = (\frac{1+i}{1+r})^4$. Debt levels obtained from the simulations are equivalent to the present value of future debt obligations and computed as $\frac{b'}{\delta+r}$.

In both cases, the income is set to the average income in the economy and the other debt level is kept at the ergodic mean level in the FD economy.[14]

In both economies, bond prices are decreasing in the debt levels. This is a result of an increase in default likelihood associated with higher total debt levels. However, in the FD economy, for a given level of borrowing choice, bond prices are lower compared to the ND economy. This non-trivial observation is the result of the two opposing effects discussed in Section 3.2.2. The absence of the negative effects of the S2S debt in the ND economy encourages the sovereign to use the S2S debt to smooth consumption as depicted in the lower panels of Figure 4. This results in lower borrowing levels for the non-contingent debt in the ND economy, which reduces the debt dilution problem the sovereign faces. As a result, the price of the non-contingent debt is higher in the ND economy.[15]

These changes in the bond prices result in shifts in the debt portfolio of the sovereign as the economy switches from the ND economy to the FD economy. As the bond prices become lower in the FD economy, the sovereign borrows less of non-state contingent debt and more from S2S loans (hidden in ND economy and transparent in FD economy). However, these effects turn out to be quantitatively small, and cannot offset the opposite effect of portfolio shift described above.

In our calibrated model, the non-state contingent debt to GDP ratio rises from 31.39 percent to 34.42 percent as the economy moves from the ND economy to the FD economy. The S2S debt to GDP ratio, on the other hand, drops from 9.15 percent to 6.56 percent. The cost of borrowing from international bond investors (endogenous sovereign spread) increases as a result of lower prices, larger debt and more frequent defaults in the FD economy.

The following subsection further explores the mechanisms that lead to the presented long-run equilibrium outcomes in the model economies.

5.3 Transition from ND Economy to FD Economy

In this section, we discuss the transitional dynamics between the ND and FD economies. The comparison is done using simulated economies under both regimes. Specifically, we simulate 100,000 observations all starting from zero debt level and ergodic income distribution. Then, we simulate two economies using the decision rules of the ND economy until the economy reaches steady-state, where the average debt levels, default rates and

[14]More specifically, the figure plots $q(b', b_c^*, y^*, g^*)$ as a function of b' both for the FD and ND economies, where b_c^*, y^* and g^* are the ergodic mean of the S2S debt and income in the FD economy.

[15]We further confirm this debt dilution channel in Section 5.5 where we study one-period version of the model which is free from debt dilution.

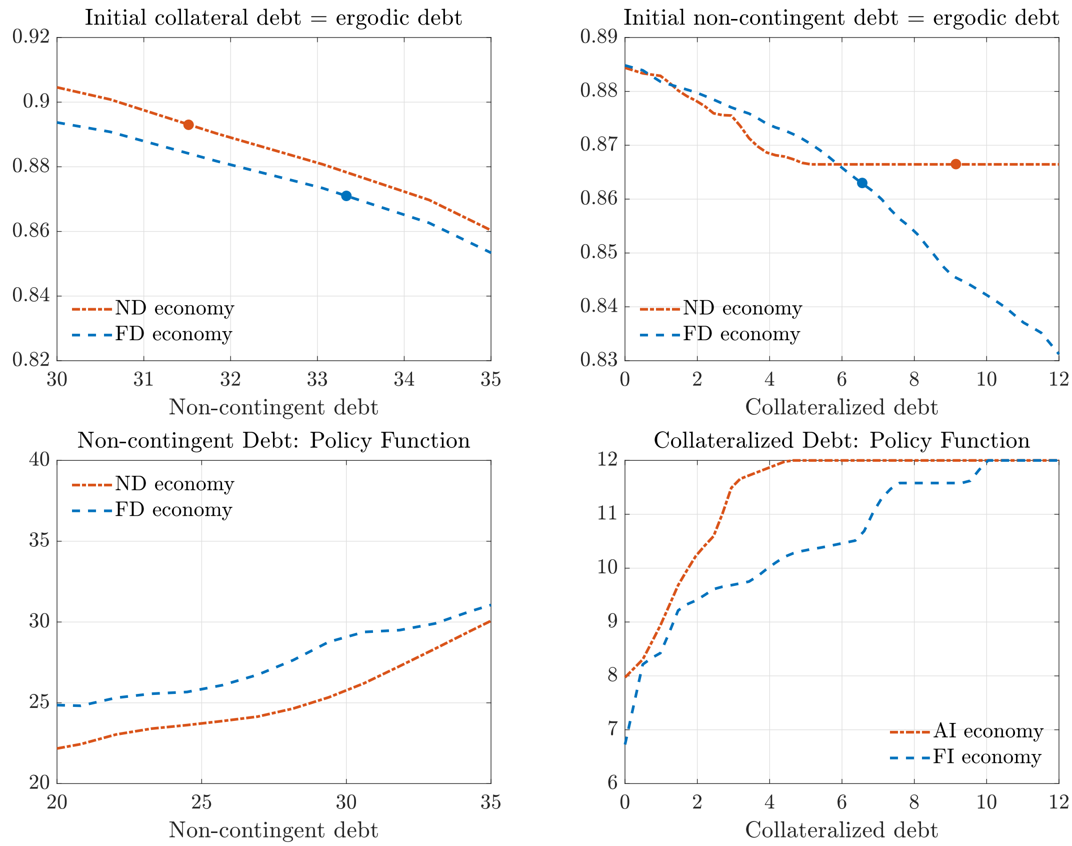

Figure 4: Bond prices and portfolio dynamics: The left upper panel plots bond pricing schedule for the non-state contingent debt as a function of current period non-contingent debt level. The right upper panel plots the same bond pricing schedule as a function of current period S2S debt level both for the FD economy (dashed lines) and the ND economy (dashed-dotted lines). The large solid dots correspond to equilibrium choices, conditional on initial states. Left lower panel plots the policy function for non-contingent debt as a function of current period non-contingent debt level whereas the right bottom panel plots the policy function for the S2S debt as a function of current period non-contingent debt. S2S debt (non-contingent debt) level on left (right) charts are set to ergodic mean level observed in simulations for the FD economy, and the endowment is set to its average value.

bond premiums are constant. Then, in one simulated economy we keep using the decision rules in the ND economy while in the other simulated economy, we switch to using the decisions rules in the FD economy. We continue this simulation until the averages reach their steady-state levels in the FD economy. Figure 5 illustrates the comparison of these two simulations starting from the switch from the ND economy to the FD economy. The plots show the average of the relative deviation of variables from their simulated counterparts in the ND economy.

Switching to the FD economy allows the sovereign to internalize the negative effects of higher S2S debt on bond prices and results in a shift from S2S debt towards non-state

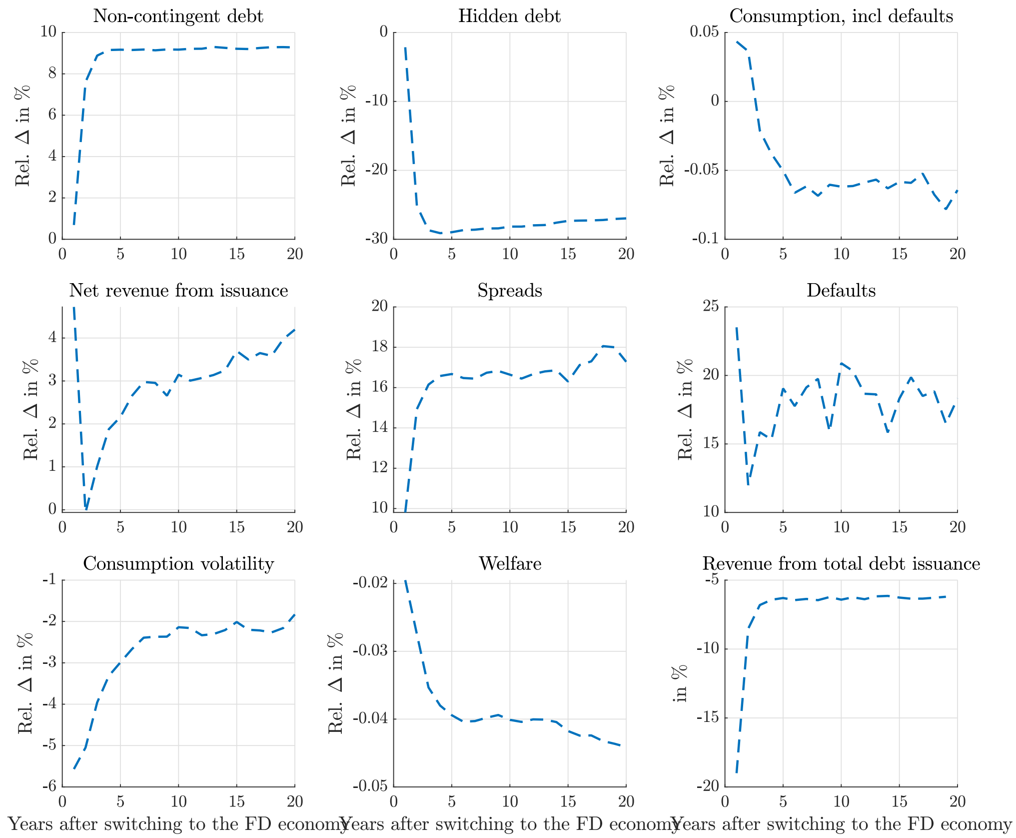

Figure 5: Transitions from the ND economy to the FD economy: debt, default. and spread when hidden debt is collateralized. Net revenue from issuance is defined as $q \times (b' - (1 - \delta)b) - \kappa b + q_c \times (b'_c - (1 - \delta_c)b_c) - \kappa_c b_c$ whereas revenue from total debt issuance is defined as $q \times (b' - (1 - \delta)b) + q_c \times (b'_c - (1 - \delta_c)b_c)$

contingent debt. As illustrated in Figure 5, non-state contingent debt to GDP ratio increases by roughly 9 percent within five years, whereas the level of S2S debt to GDP ratio was cut by 30 percent to roughly 6.5 percent of GDP. Since both debt types are long-term, the adjustment of the portfolio happens gradually. In about five years, both debt levels converge to their ergodic states, as reported in Table 8.

The level of consumption rises by about 0.05 percent on impact of the change to the FD economy. However, consumption quickly deteriorates and reaches to levels lower than the ND economy in the long-run. After 10 years, consumption reaches to its new level, which is a little more than 0.05 percent lower than its level in the ND economy.

An important reason for the gradual decline in consumption is the portfolio reshuffling the sovereign goes through in the first few years of the transition. As the S2S debt gradually declines and non-contingent debt increases to its new steady-state level, the sovereign faces lower prices for the non-contingent debt in the FD economy, where the level of hidden (S2S) debt is fully revealed. This is also reflected in the initial spike in the average spread of non-contingent debt. The increase in spreads increases the cost of rolling over the non-contingent debt, decreases the level and volatility of consumption in the initial years of the transition.

As the portfolio rebalances, non-contingent debt levels rise, leading to higher default rates and spreads. This increase in defaults explains the long-term decline in the *Consumption, incl defaults* chart. Welfare follows the consumption and default patterns, showing lower welfare both immediately and in the long run in the FD economy. Next, we examine the welfare dynamics further.

5.4 Welfare Implications

In this section, we compute state-dependent welfare gains in terms of percentage changes in compensating consumption variations that would leave a government indifferent between staying in the ND economy or switching to the FD economy. We measure consumption-equivalent welfare gains denoted by η as,

$$\mathbb{E}_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} u\left(c_\tau^{ND}[1+\eta] | b_t, b_t^c, s_t\right) = \mathbb{E}_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} u\left(c_\tau^{FD} | b_t, b_t^c, s_t\right), \tag{18}$$

in which the consumption streams $\{c_\tau^{ND}\}_{\tau=t}^{\infty}$ and $\{c_\tau^{FD}\}_{\tau=t}^{\infty}$ are attained in the ND and FD economies, respectively. Welfare gain measure η is evaluated conditional on initial non-contingent debt, hidden debt and endowment and is derived from equilibrium value functions with

$$\eta(b_t, b_t^c, s_t) = \left(\frac{V^{FD}(b_t, b_t^c, s_t)}{V^{ND}(b_t, b_t^c, s_t)}\right)^{\frac{1}{1-\gamma}} - 1, \tag{19}$$

utilizing the CRRA form for household preferences. $V^{FD}(b_t, b_t^c, s_t)$ and $V^{ND}(b_t, b_t^c, s_t)$ are value functions evaluated for triplets of hidden debt b_t^c, non-contingent debt b_t and output s_t in the FD and ND economies, respectively. Positive values for η imply that the benevolent government would prefer to make its hidden debt information public.

Table 4 reports the average welfare change at the time of the switch from ND economy to FD economy.[16] We find that moving from the ND economy to the FD economy generates average welfare loss of 0.020% at the time of the change. Although the welfare change is small and negative, there is considerable variation in the welfare change across

[16] The averages are computed using the formula $\int \eta(b_t, b_t^c, s_t) d\Gamma^{ND}(b_t, b_t^c, s_t)$, where Γ^{ND} is the steady-state distribution of states for the sovereign in the ND economy.

Table 4: Decomposition of welfare gains at the time of switch

Welfare gain from cons. paths (%)	-0.020
From tilting consumption (%)	0.009
From lowering income cost of defaulting (%)	-0.036
From lowering consumption volatility (%)	0.008

Notes: The table shows the decomposition of average welfare changes at the time of switch from the ND economy to the FD economy. The welfare calculations follow the methodology presented in Aguiar et al. (2020). See Appendix A.2 for more details.

states as shown in the left panel of Figure 6. At the time of the switch for the majority of states, the welfare gain is negative, but in some states the welfare gain is slightly positive.

To better understand the composition of welfare changes, Table 4 reports the sources of welfare gains following the approach of Aguiar et al. (2020). The details of the decomposition can be found in Appendix A.2. The table shows that the most of the welfare losses are accounted for by an increase in default frequency following a switch to the FD economy. While front-loaded consumption profile and lower volatility in the FD economy cause an increase in the welfare around 0.017%, this gain is dominated by increased default frequency and its associated costs due to output losses, which generate a welfare loss of 0.036%. Overall, the welfare change becomes negative.

As depicted in the bottom panel of Figure 5, welfare losses become more pronounced after a few years and reaches to the level of 0.05 percent after 10 years. Table 5 shows the decomposition of welfare changes in the long-run. Similar to the effects at the time of switch, majority of welfare changes is due to an increase in default frequency due to higher levels of non-contingent debt borrowing thanks to lower cost of debt issuance for the non-contingent debt.

The right panel of Figure 6 plots the heterogeneity in the welfare changes in the ergodic distribution of the FD economy. There is again sizable heterogeneity in the welfare changes. In some states the welfare gain can be as large as 3% whereas in some other states the welfare loss can be as large as 2%.

5.5 Short-term Debt

To sharpen our understanding of the model mechanism, we solve the model with one-period debt so that we can discipline the effect of debt dilution on our welfare loss results with long-term debt from switching to the full disclosure regime. Under long-term debt,

Table 5: Decomposition of welfare gains in the long-run

Welfare gain from cons. paths (%)	-0.060
From tilting consumption (%)	0.009
From lowering income cost of defaulting (%)	-0.060
From lowering consumption volatility (%)	0.008

Notes: The table shows the decomposition of average welfare changes between the ergodic distribution of the ND and the FD economy. The welfare calculations follow the methodology presented in Aguiar et al. (2020). See Appendix A.2 for more details.

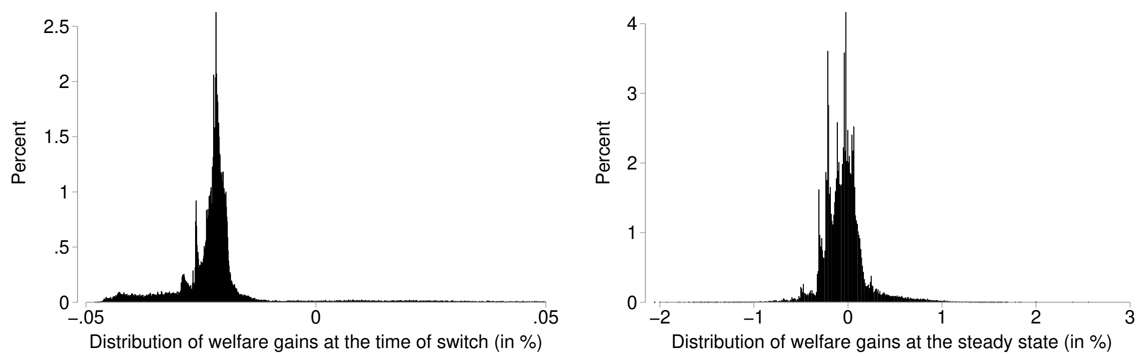

Figure 6: The left panel shows the distribution of welfare changes at the time of the switch and the right panel shows the distribution of the welfare changes across steady-states.

current governments cannot constrain future governments' debt issuances. As lenders anticipate that any future government's additional debt issuance will increase the current government's issued debt, they offer a lower price (see Hatchondo et al., 2016). Yet, for one-period debt contracts, this is not a concern and sequential decisions are also optimal from time zero perspective. Thus, our analysis with one-period debt below sheds light on the model's key mechanism on welfare losses.

We first re-calibrate our one-period model economy and we report the long-run statistics in Table 6. Leaving the discussion of these details to Guler et al. (2022), we proceed by presenting our welfare decomposition analysis as this is the key part of the analysis.[17]

Intriguingly, contrary to long-term debt results, Figure 7 shows that the economy now enjoys welfare gains following a switch to the FD economy for each standard deviation of innovations level that is considered in the long-term debt economy. Table 7 reports the welfare decomposition for the baseline scenario, similar to the welfare decomposition

[17] An earlier version of the paper did not have Nash bargaining over defaulted debt, while also assuming a constant rate for S2S debt. The qualitative implications are very similar.

Table 6: Short-term debt model and data

	Data	Benchmark (ND)	FD
Targeted moments			
Non-contingent debt service/GDP, percent	8.94	12.52	15.58
Hidden debt service/GDP, percent	2.43	1.86	2.87
Interest rate, $E(R_s)$, percent	2.57	2.90	2.77
Recovery rate	63	48.02	52.90
Non-targeted moments			
$\sigma(c)$ / $\sigma(y)$	1.22	1.42	1.57
$\rho(c, y)$	0.81	0.95	0.92

Notes: ND and FD stand for nondisclosure and disclosure respectively. For calibration, we set d_0 = -1.2 and d_1 = 1.255, the discount factor β = 0.88 and, the S2S debt holders discount factor β^* = 0.88.

Table 7: Decomposition of welfare gains for short-term debt model

	Baseline
Welfare gain from cons. paths (%)	0.240
From tilting consumption (%)	0.193
From lowering income cost of defaulting (%)	0.075
From lowering consumption volatility (%)	-0.028

Notes: The welfare calculations follow the methodology presented in Aguiar et al. (2020). See Appendix A.2 for more details.

with long-term debt. The table shows that the increase in default frequency following a switch to the FI economy accounts for an important share in decomposition dynamics. But, with one-period debt contracts, consumption front-loading outweighs the losses induced by increased default frequency. Overall, the welfare change becomes positive. This analysis confirms our conjecture that welfare losses in our main analysis is associated with the debt-dilution problem that is inherited with long-term debt.

5.6 Defaultable Hidden Debt

In our main analysis, we assumed that the hidden debt is non-defaultable. This assumption is supported by the fact that a portion of such non-transparent debt can be securitized through projects and include collateral, making default less likely. However,

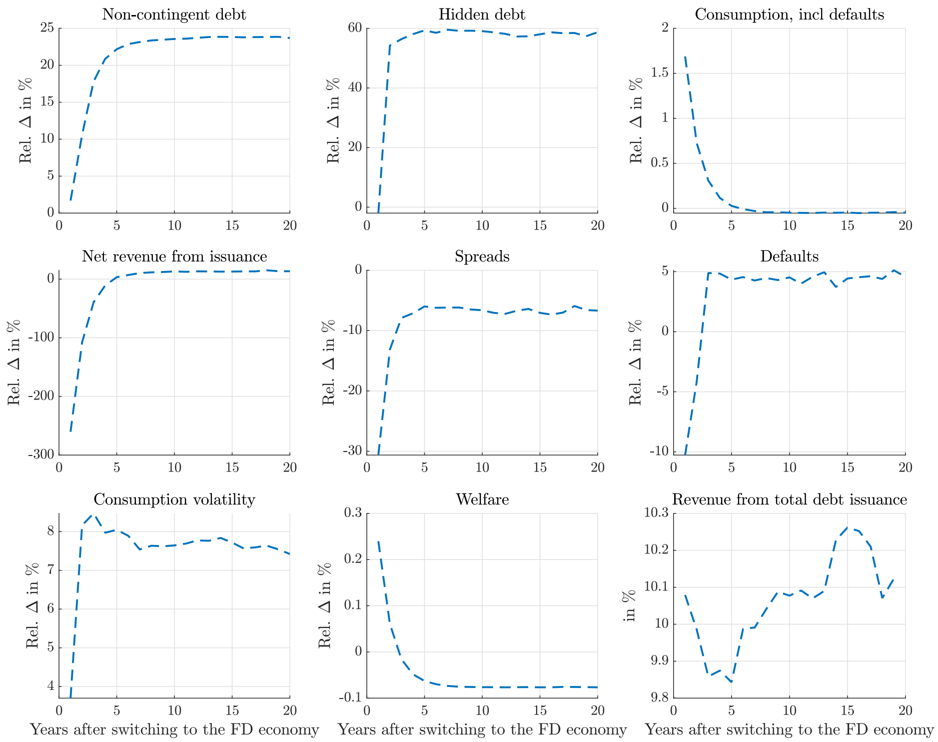

Figure 7: Transitions from ND economy to FD economy: debt, default. and spread with short-term debt.

we also consider a version of the model where the S2S debt is defaultable, while its price still follows the same stochastic discount factor as in equation (9). If the sovereign defaults on the S2S debt, the endogenous haircut rate on the S2S debt becomes identical to that of the non-contingent debt. Consequently, equation (12) becomes:

$$
\begin{aligned}
V^d\left(b, b_c, s\right) = {} & u\left(y - \phi(y)\right) \\
& + \beta\, \mathbb{E}_{s'|s}\left[\psi\, V^r\left(\hat{\alpha}(b, b_c, s')b, \hat{\alpha}(b, b_c, s')b_c, s'\right)\right. \\
& \left. + \left(1 - \psi\right) V^d\left(b, b_c, s'\right)\right].
\end{aligned} \tag{20}
$$

where the equilibrium recovery rate is given by

$$
\begin{aligned}
\hat{\alpha}(b, b_c, s) = \arg\max_{\alpha\in[0,1]} & \left\{\left[V^r(\alpha b, \alpha b_c, s) - V^d(b, b_c, s)\right]^{\phi}\right. \\
& \left.\left[MV^r(\alpha b, \alpha b_c, s) - MV^d(b, b_c, s)\right]^{1-\phi}\right\},
\end{aligned}
$$

the market value of a debt portfolio is given by

$$MV^r(b,b_c,s) \quad = \quad \kappa b + (1-\delta)bq(\hat{b}(b,b_c,s),\hat{b}_c(b,b_c,s),s)$$

outside default and

$$MV^d(b,b_c,s) \quad = \quad bq^D(b,b_c,s),$$

in default, the price of non-contingent bonds is given by

$$(1+r^*)q\left(b',b_c',s\right) \quad = \quad \mathbb{E}_{s'|s}\left\{\left[(1-d')\left[(1-\delta)q\left(b'',b_c'',s'\right)+\kappa\right]+d'q_d\left(b',b_c',s'\right)\right]\right\},$$

outside default and

$$\begin{aligned}
&q_d\left(b',b_c',s\right) = \\
&\mathbb{E}_{s'|s}\left\{\left[\psi\,\hat{\alpha}(b',b_c',s')\left(\left[\kappa+(1-\delta)q\left(\hat{b}\left(\hat{\alpha}b',\hat{\alpha}b_c',s'\right),\hat{b_c}\left(\hat{\alpha}b',\hat{\alpha}b_c',s'\right),s'\right)\right]\right)\right.\right. \\
&\left.\left.+(1-\psi)q_d\left(b',b_c',s'\right)\right]\right\},
\end{aligned}$$

in default.

Table 8 reports the corresponding moments of the model. The table shows stark similarities to its defaultable counterpart, Table 8. Specifically, the ND economy features more S2S debt and less non-contingent debt compared to the FD economy. Although the FD economy can achieve lower consumption volatility, it defaults more frequently than the ND economy, resulting in higher spreads in the FD economy.

Table 8: Long-run statistical moments

	Data	ND	FD
Targeted moments			
Non-contingent debt/GDP (%)	30.23	22.38	27.21
S2S (hidden) debt/GDP (%)	8.20	9.27	6.84
Mean spread, $E(R_s)$(%)	2.57	2.04	2.84
Duration, years	3	3.07	3.02
Recovery rate (%)	63	59.8	58.9
Non-targeted moments			
Default rate (%)	5	6.15	6.93
$\sigma(c)\ /\ \sigma(y)$	1.22	1.17	1.12
$\sigma(tb)/\sigma(y)$	0.51	0.72	0.70
$\rho(c,y)$	0.81	0.98	0.97

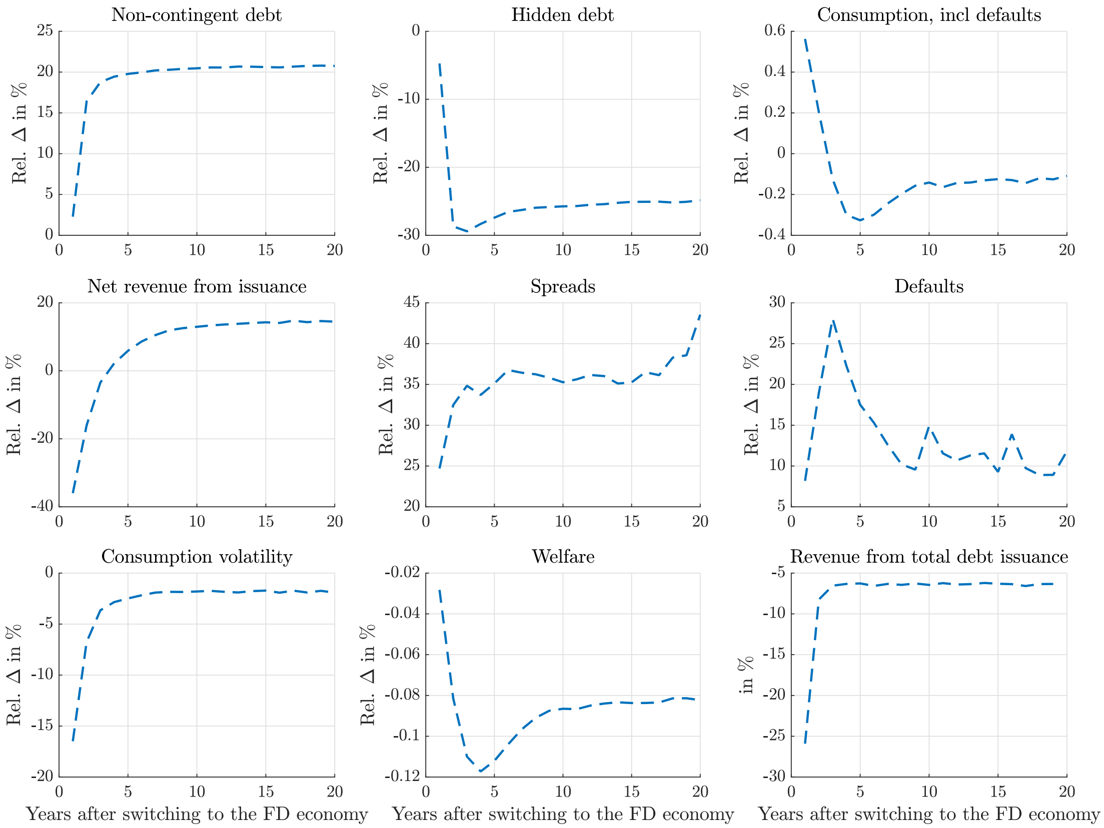

Figure 8: Transitions from ND economy to FD economy: debt, default. and spread when hidden debt is defaultable. Net revenue from issuance is defined as $q \times (b' - (1-\delta)b) - \kappa b + q_c \times (b'_c - (1-\delta_c)b_c) - \kappa_c b_c$ whereas revenue from total debt issuance is defined as $q \times (b' - (1-\delta)b) + q_c \times (b'_c - (1-\delta_c)b_c)$.

Transitional Dynamics: When S2S debt is defaultable, as shown in Figure 8, the transitional dynamics also show a similar pattern in comparison to the case where S2S debt is collateralized but with some nuanced differences. First, the change in the portfolio composition towards the non-contingent debt is more significant. The risk of default on S2S debt, in this case, implies an additional risk premium to the prices, resulting in a larger price gain when the economy switches to the FD environment. Therefore, the level of hidden debt drops and the non-contingent debt increases by larger amounts in comparison to the non-defaultable hidden debt model.

Even though some quantitative differences exist, the transition with defaultable debt does not result in qualitative differences for key variables. Specifically, the evolution of consumption, spreads, defaults, and welfare remains consistent. In terms of quantitative differences, in contrast to the non-defaultable case, the consumption jump is sizable at

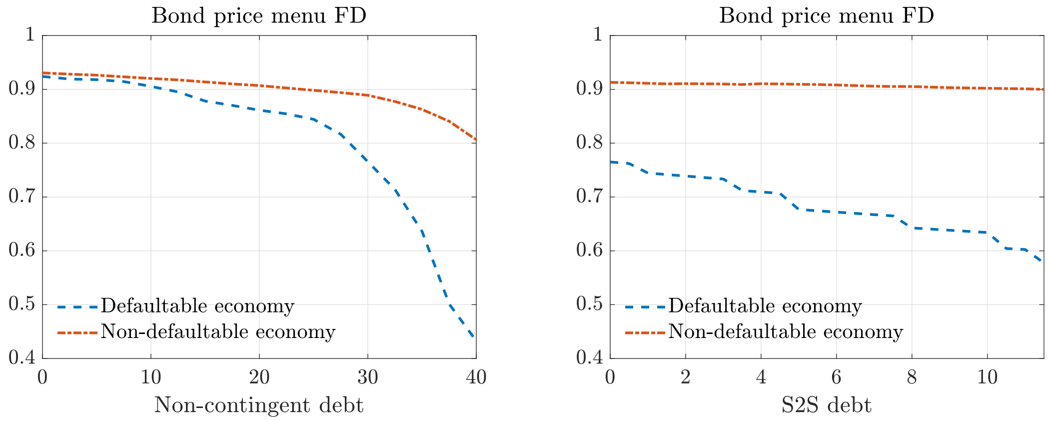

Figure 9: Bond prices: The left panel plots bond pricing schedule for the non-state contingent debt as a function of current period non-contingent debt level. The right panel plots the same bond pricing schedule as a function of current period hidden debt level for the FD economy when hidden debt is non-defaultable (dashed lines) and when hidden debt is defaultable (dashed-dotted lines). Hidden debt (non-contingent debt) level on left (right) charts are set to ergodic mean level observed in simulations for the FD economy when debt is non-defaultable, and the endowment is set to its average value.

the time of the switch and gradually converges to a level lower than its level in the ND economy. Welfare follows a similar pattern, but the long-run welfare losses are more pronounced than in the ND economy. Similarly, the jump in spreads is more sizable and increases in the long run.

What explains these differences? The main difference of the economy with defaultable debt compared to the non-defaultable debt is the sensitivity of the non-contingent debt price to the level of hidden debt as shown in Figure 9. When hidden debt is defaultable, the price of non-contingent debt becomes more sensitive to the level of hidden debt. As hidden debt increases the decline in the price of non-contingent debt becomes larger. This makes the change in the price of contingent debt when the economy switches from the ND to FD environment larger. When hidden debt becomes transparent, the negative effects of informational frictions on the bond price vanish, and the sovereign faces better prices conditional on the same fundamentals. This encourages a further shift of portfolio from hidden debt to non-contingent debt. Notice that this effect is in addition to the portfolio shift which happens when the borrower starts internalizing the negative effects of the hidden debt on the price of the non-contingent debt as the hidden debt becomes transparent. As a result, the quantitative effects are larger for the portfolio shift.

With better bond prices, the impatient government front-loads consumption, and consumption increases in the short-run. However, this comes at the cost of larger debt levels for the sovereign. Thus, in the long-run default increases with further rise in spreads with

Table 9: Decomposition of welfare gains

Welfare gain from cons. paths (%)	-0.029
From tilting consumption (%)	0.004
From lowering income cost of defaulting (%)	-0.016
From lowering consumption volatility (%)	-0.018

Notes: The welfare calculations follow the methodology presented in Aguiar et al. (2020). See Appendix A.2 for more details.

a decrease in consumption over time. Eventually, the negative effects of higher debt, due to debt dilution, outweighs the positive effects of improved prices, and welfare becomes lower compared to the ND economy in the long-run.

Welfare Decomposition: Table 9 shows that, similar to the case with non-defaultable hidden debt, at the time of the switch welfare falls for the sovereign with defaultable hidden debt. The intuition is that if hidden debt is non-defaultable, lenders are not "much" worried as non-defaultable debt makes defaulting costlier (recall that the government is not allowed to borrow any debt during default but required to pay coupons of hidden debt). However, in the long run, due to debt dilution, the sovereign accumulates larger debt and ends up with higher default frequency, which in turn lowers the welfare over time.

Similar to the case when hidden debt is non-defaultable, at the time of the switch, the bulk of the welfare changes happens due to changes in default frequency and consumption tilting. The switch causes the welfare to drop mainly due to the increased default frequency, which generates a welfare loss of 0.029% while consumption front-loading profile presented in Figure 8 slightly counteracts the decline in welfare by 0.004%. Similar to the case with defaultable debt, both at the time of the switch and across steady-states, there is considerable variation in welfare changes, and there is much concentration of states with welfare gains as shown in Figure 10.

6 Conclusion

This paper is motivated by the increasing prevalence of non-Paris Club lending in the global capital markets. We aim to explore the dynamics of sovereign debt and default under different disclosure arrangements. While the impact of financial disclosure on corporate borrowing is well-studied, there is a gap in the literature regarding how sovereign debt and default are affected by disclosure arrangements. This intersection of research ar-

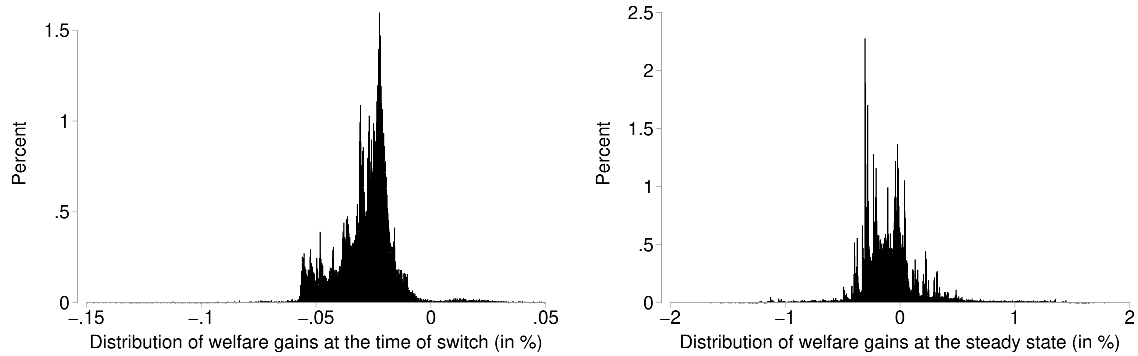

Figure 10: The left panel shows the distribution of welfare changes at the time of the switch and the right panel shows the distribution of the welfare changes across steady-states.

eas has prompted us to develop a model that takes into account the impact of asymmetric information on government borrowing and sovereign default.

We have expanded upon existing quantitative models of sovereign default analysis by incorporating several new factors, including situations where the amount of asset borrowing is not disclosed, a portfolio consisting of two assets, and long-term debt. In our analysis, we assume that the government has access to both international bond financing and non-Paris Club lending, which is a hidden and collateralized sovereign-to-sovereign loan.

Our results show that the sovereign does not fully internalize the effects of hidden debt choice on asset prices which reduces the cost of holding hidden debt. However, under full transparency, governments tend to shift their borrowing towards more of non-contingent debt and less of hidden debt, therefore a higher default likelihood and borrowing spread in the long-run equilibrium. As a result, the switch from nondisclosure economy to full disclosure economy returns small welfare losses.

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A Appendix

A.1 Lack of Transparency in Sovereign Debt Disclosure

Sovereign debt transparency in developing and emerging economies has recently gained global attention for a variety of important reasons. Over the course of the past decade, the funding needs and the levels of public debt increased substantially in developing economies, with a significant deterioration during the COVID-19 pandemic (OECD, 2022; World Bank, 2021). This is combined with the remarkable change in the landscape of international lending, with a rise in non-traditional borrowing practices such as non-Paris Club loans which are subject to opaque borrowing practices (Horn et al., 2021). The existing sovereign debt disclosure practices in these countries resulted in repeated calls for more transparent reporting and monitoring procedures by World Bank, IMF, OECD, and the G-20 countries. Most recently, World Bank initiated the multilateral debt restructuring program, Debt Service Suspension Initiative (DSSI), which involves debt payment delays

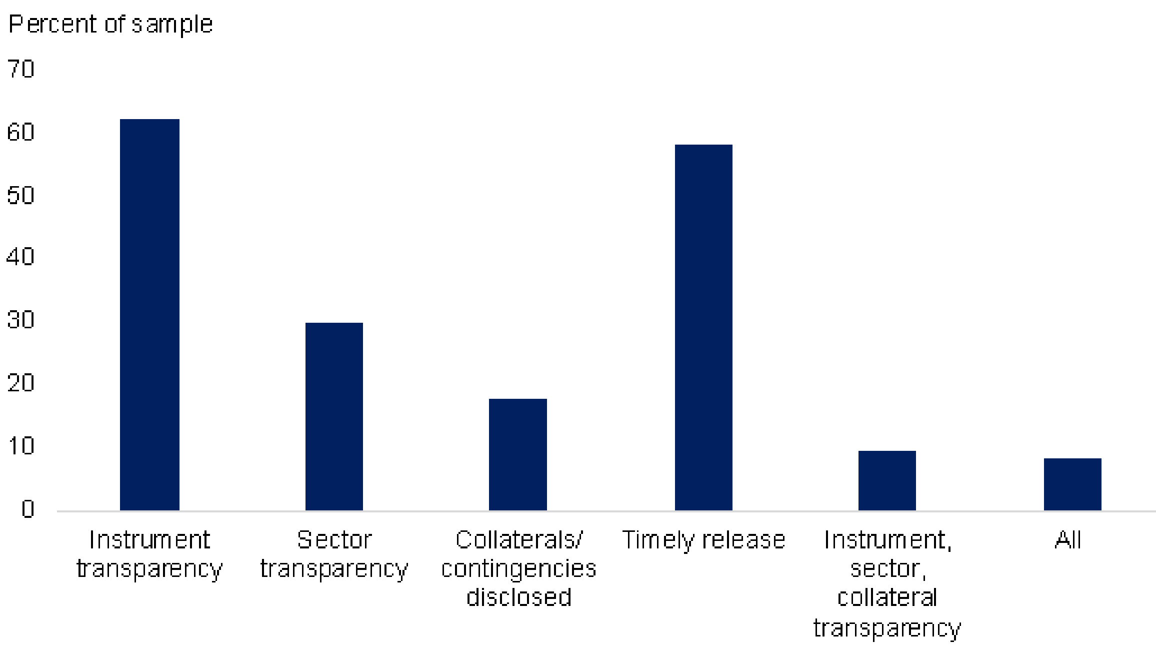

Figure A.1: The axis labels are defined as follows. *Instrument transparency:* Debt instruments include external debt, domestic debt, and guarantees by central governments. *Sector transparency:* Public debt covers the liabilities of both general government and state-owned enterprises. *Collaterals/contingencies disclosed:* disclosure of central government guarantees, account payables, collateralization details, and debt-related contingent liabilities. *Timely release:* Debt details are disclosed with a maximum six-month lag and at least annually. The calculations are based on the data source's classification for a sample of 74 countries. Data source: World Bank.

conditional on improved debt disclosure practices (OECD, 2022; World Bank, 2021; IMF, 2020).[18]

Debt transparency refers to the availability of information regarding borrowing operations in general. This includes comprehensive, timely, and consistent debt statistics based on international definitions and concepts, as well as clearly defined financial terms and clear legal implications based on legitimate contracts free from undue political interference. Providing detailed evidence on debt disclosure practices is a challenge due to lack of a comprehensive database and discrepancy among the existing partial ones. World Banks Debt Transparency Heat Map is a promising venue, providing a recent snapshot of disclosure practices in 74 countries. The database collects information on dissemination of public debt statistics from national authorities. It decomposes debt transparency practices into 9 categories: data accessibility, instrument coverage, sector coverage, coverage of recently signed external contracts, release frequency, lag in reporting, collateral and contingency information, debt management strategy, and annual borrowing plan. Each category is scored between 1 and 4, with 1 representing the no information availability and 4 the highest transparency.[19]

Figure A.1 presents the recent picture of debt disclosure practices in developing economies. Only 18 percent of the sample countries report details about collateral and contingent claims in their borrowings, according to the results of the most recent assessment in 2021. Only 9.5 percent of countries report external and domestic debt separately, for both public and publicly guaranteed borrowing, and report collateral and contingent claims transparently at the same time. While nearly 60 percent of countries release debt statistics on a timely basis (annually or more frequently with less than a six-month lag), only 8 percent of those countries disclose key debt details. Overall, the disclosure figures paint an opaque picture of debt disclosure practices in developing economies. Alternative databases such as USAIDs Debt Transparency Scorecard and IMFs Fiscal Transparency Evaluations point to the same result for various set of countries and alternative definitions of transparency (USAID, 2022; IMF, 2014). It is worth noting that incomplete disclosure practices persist, despite recent calls by international organizations and initiatives such as DSSI that aim to provide incentives for full disclosure implementation.

[18]See the following link for further details on the DSSI program: `https://www.worldbank.org/en/programs/debt-statistics/dssi`.

[19]See World Bank (2021) for further details on the World Bank's Debt Transparency Heat Map.

A.2 Welfare Decomposition

In this section, we provide the details of the welfare decomposition we conduct in Section 5.4 following Aguiar et al. (2020). Let $\left\{c_t^{ND}, c_t^{FD}\right\}$ denote the consumption function derived in the nondisclosure and disclosure economies, respectively. Then, the welfare of the sovereign in the ND economy conditional on state $s_0 \equiv \left\{b_0, b_0^c, y_0, g_0\right\}$, where y_0 is the existing income, b_0 is the existing non-state contingent debt and b_0^c is the existing hidden debt, is computed

$$W^{ND}\left(s_0\right) = E_0 \sum_{t=0}^{\infty} \beta^t u\left(c_t^{ND}\right)$$

and average welfare is computed by

$$\hat{W}^{ND} = \int W^{ND}\left(s_0\right) d\Gamma^{ND}\left(s_0\right)$$

where Γ^{ND} is the steady-state distribution of the income and debt levels for the sovereign.

Similarly, in the FD economy, we have

$$\hat{W}^{FD} = \int W^{FD}\left(s_0\right) d\Gamma^{FD}\left(s_0\right)$$

where

$$W^{FD}\left(s_0\right) = E_0 \sum_{t=0}^{\infty} \beta^t u\left(c_t^{FD}\right)$$

and Γ^{FD} is the steady-state distribution in the FD economy.

To isolate the effect of default induced output loss in welfare, we define counterfactual consumption functions $c_t^{ND,nd}$ and $c_t^{FD,nd}$ with lower case nd denoting no-default such that

$$\begin{aligned} c_t^{ND,nd}\left(s_t\right) &= c_t^{ND}\left(s_t\right) + d_t^{ND}\left(s_t\right)\phi\left(y_t\right) \\ c_t^{FD,nd}\left(s_t\right) &= c_t^{FD}\left(s_t\right) + d_t^{FD}\left(s_t\right)\phi\left(y_t\right) \end{aligned}$$

where d_t^{ND} and d_t^{FD} are the default decisions in the ND economy and FD economy, respectively, and $\phi\left(y_t\right)$ is the output loss due to default. These counterfactual consumption functions compute the corresponding consumption for the sovereign if the sovereign follows the same debt and default rules but not incur output loss during default.

To compute the welfare change due to change in consumption volatility, we define expected consumption without default output losses:

$$\bar{c}_t^{ND,nd}(s_0) = E_t\left[c_t^{ND,nd}(s_t)\,|s_0\right]$$
$$\bar{c}_t^{FD,nd}(s_0) = E_t\left[c_t^{FD,nd}(s_t)\,|s_0\right]$$

Given these consumption functions, we define

$$W^{i,nd} = \int E_0 \sum_{t=0}^{\infty} \beta^t u\left(c_t^{i,nd}\right) d\Gamma^i(s_0)$$
$$\bar{W}^{i,nd} = \int \sum_{t=0}^{\infty} \beta^t u\left(\bar{c}_t^{i,nd}\right) d\Gamma^i(s_0)$$

where $i \in \{ND, FD\}$. Here $W^{ND,nd}$ denotes the average expected welfare computed using the consumption functions without default output losses, and $\bar{W}^{FD,nd}$ is the average expected welfare computed using the expected consumption functions without default output losses.

Then, we can decompose the change in welfare when the economy switches from ND economy to FD economy as:

$$\underbrace{\left(\frac{W^{FD}}{W^{ND}}\right)^{\frac{1}{1-\gamma}}}_{1+\lambda} = \underbrace{\left(\frac{W^{FD}/W^{FD,nd}}{W^{ND}/W^{ND,nd}}\right)^{\frac{1}{1-\gamma}}}_{1+\lambda_D} \times \underbrace{\left(\frac{W^{FD,nd}/\bar{W}^{FD,nd}}{W^{ND,nd}/\bar{W}^{ND,nd}}\right)^{\frac{1}{1-\gamma}}}_{1+\lambda_V} \times \underbrace{\left(\frac{\bar{W}^{FD,nd}}{\bar{W}^{ND,nd}}\right)^{\frac{1}{1-\gamma}}}_{1+\lambda_T}$$

where λ is the overall change in welfare across two economies. Here, λ_D captures the welfare change due to change in default output losses generated by differential default episodes in both economies. The second term λ_V captures the welfare change due to change in consumption volatility across two economies. Lastly, λ_T captures the welfare change due to change in consumption levels across two economies.

A.3 Robustness

A.3.1 Debt duration, financial exclusion, discount factor

Table A.1 provides a robustness analysis for varying degrees of debt maturities of non-contingent debt and S2S debt, δ and δ_c, different parameterizations of the exclusion parameter ψ, as well as alternative parameterizations of the discount factor β. Specifically, we experiment with an approximately 6-year duration parameter by setting both δ and δ_c

to 0.117, we experiment with 3 and 5 years of exclusion when the government defaults, and lastly we alternate the discount factor to 0.93 and 0.91.

The following observations stand out. The model dynamics presented in the manuscript remain qualitatively consistent, with only quantitative differences observed. This outcome is plausible and expected, as we have not entirely recalibrated the model but instead changed only one parameter at a time. Specifically, the dynamics of the portfolio, spreads, defaults, consumption volatility, and welfare remain consistent. Exceptions arise when the average exclusion is set to 3 years and the discount factor is set to 0.93.

When the exclusion period is set to 3 years, we observe a negligible welfare gain of 0.0002% when the government transitions from the ND economy to the FD economy. Additionally, with a discount factor of 0.93higher than the baseline of 0.92there are positive welfare gains. Conversely, a lower discount rate of 0.91 exacerbates welfare losses.

One intuition for this outcome is that with a higher discount factor, the sovereign defaults less on average after switching to the FD economy, resulting in a smaller deadweight loss. Additionally, as the sovereign has a higher discount rate, future consumption declines have a greater impact on welfare.

Table A.1: Long-run statistical moments

	Maturity		Exclusion				Discount factor			
	(1) ND	(2) FD	(3) ND	(4) FD	(5) ND	(6) FD	(7) ND	(8) FD	(9) ND	(10) FD
Non-contingent debt/GDP (%)	32.27	36.58	37.17	39.09	44.48	46.96	31.58	31.16	33.91	36.95
S2S (hidden) debt/GDP (%)	10.53	9.11	8.76	6.29	8.24	5.52	4.90	7.00	10.35	8.18
Mean spread, E(Rs)(%)	3.01	3.48	1.77	1.79	1.31	1.44	1.69	1.77	2.32	2.62
Duration, years	5.69	5.58	3.08	3.08	3.11	3.1	3.09	3.09	3.05	3.03
Recovery rate (%)	57.23	56.51	61.62	61.45	59.1	57.54	61.74	61.62	64.06	60.59
Default rate (%)	6.53	7.21	3.5	3.62	2.04	2.25	4.75	4.96	5.75	6.77
$\sigma(c)$ / $\sigma(y)$	1.08	1.03	1.23	1.19	1.32	1.27	1.04	1.05	1.25	1.23
$\sigma(tb)/\sigma(y)$	0.53	0.6	0.8	0.7	1.17	0.97	0.58	0.54	0.82	0.75
$\rho(c, y)$	0.98	0.97	0.99	0.99	0.98	0.98	0.98	0.98	0.99	0.99
Welfare gains (%)		-0.03		0		-0.02		0.02		-0.08

The first two columns are obtained by setting both δ and δ_c to 0.117. Columns (3) and (4) are obtained by setting $\psi = 1/3$ to obtain 3 years of exclusion while columns (5) and (6) are obtained setting $\psi = 1/5$ to obtain 5 years of exclusion. Columns (7) and (8) are obtained by setting $\beta = 93$ while columns (9) and (10) are obtained by setting $\beta = 91$. Welfare gains row presents welfare gains obtained from switching from the ND economy to the FD economy.

A.3.2 Borrower's bargaining power

Table A.2 provides a series of robustness tests for varying degrees of borrowers bargaining power, ϕ. When the borrower has high bargaining power, it typically results in a lower recovery rate, or in other words, a higher haircut on the defaulted debt. Consequently, the government can sustain lower levels of debt in equilibrium because the cost of defaulting is reduced. With lower debt levels, the debt dilution problem is also mitigated, potentially leading to slight welfare gains. Conversely, when lenders have higher bargaining power, the recovery rate on defaulted debt increases, potentially allowing lenders to recoup all the surplus, resulting in a recovery rate of 100%. This outcome is intuitive and consistent with existing sovereign default models that incorporate debt renegotiation (see Yue, 2010).

The portfolio dynamics discussed in the manuscript remain consistent. In the ND economy, the government holds more hidden debt and less non-contingent debt. After transitioning to the FD economy, the government undergoes portfolio reshuffling and holds less S2S (sovereign-to-sovereign) debt compared to the ND economy.

Table A.2: Long-run statistical moments

	ϕ=0.90		ϕ=0.95		ϕ=0.975		ϕ=0.99	
	(1) ND	(2) FD	(3) ND	(4) FD	(5) ND	(6) FD	(7) ND	(8) FD
Non-contingent debt/GDP (%)	40.45	41.71	27.67	29.68	20.88	22.52	16.35	22.52
S2S (hidden) debt/GDP (%)	8.08	5.56	9.24	7.51	9.63	8.14	9.84	8.14
Mean spread, E(Rs)(%)	1.93	1.97	2.14	2.37	2.27	2.48	2.66	2.48
Duration, years	3.08	3.07	3.06	3.05	3.05	3.04	3.03	3.04
Recovery rate (%)	61.94	60.69	57.81	60.02	53.41	51.98	37.99	51.98
Default rate (%)	7.4	7.23	4.68	5.35	4.13	4.46	3.69	4.46
$\sigma(c)$ / $\sigma(y)$	1.17	1.21	1.19	1.14	1.19	1.14	1.19	1.14
$\sigma(tb)/\sigma(y)$	0.64	0.89	0.68	0.6	0.73	0.66	0.76	0.66
$\rho(c,y)$	0.98	0.97	0.99	0.99	0.99	0.99	0.98	0.99
Welfare gains (%)		-0.05		-0.0		-0.008		0.01

The first two columns are obtained by setting ϕ=0.90, columns (3) and (4) are obtained by setting ϕ=0.95, columns (5) and (6) are obtained by setting ϕ=0.975, and columns (7) and (8) are obtained by setting ϕ=0.99. Welfare gains row presents welfare gains obtained from switching from the ND economy to the FD economy.

A.3.3 S2S bond holders' risk aversion

Table A.3 demonstrates that the model dynamics remain robust when varying the S2S debt holders' risk aversion parameter, γ^*, which ranges from 5 to 45 in the table. As the risk aversion of S2S debt holders increases, the premium they demand decreases, making S2S debt issuance more favorable for the borrower. Consequently, as the borrower issues more S2S debt, the dynamics described in the text become more pronounced. Specifically, the borrower prefers to issue more hidden debt and less non-contingent debt in the ND economy. Additionally, the borrower is subject to welfare losses when switching from the ND economy to the FD economy.

Table A.3: Long-run statistical moments

	γ^*=45		γ^*=35		γ^*=25		γ^*=15		γ^*=5	
	(1) ND	(2) FD	(3) ND	(4) FD	(5) ND	(6) FD	(7) ND	(8) FD	(9) ND	(10) FD
Non-contingent debt/GDP (%)	32.18	34.55	31.66	34.15	31.36	35.45	31.95	33.02	32.82	34.48
S2S (hidden) debt/GDP (%)	7.93	5.75	6.74	4.45	9.02	6.89	8.51	6.31	7.68	4.89
Mean spread, E(Rs)(%)	1.77	2.29	1.75	2.18	1.81	2.33	1.94	2.23	2.18	2.25
Duration, years	3.08	3.05	3.09	3.06	3.08	3.05	3.07	3.06	3.06	3.06
Recovery rate (%)	61.96	62.4	61.41	59.72	64.67	61.86	58.73	59.93	63.16	61.24
Default rate (%)	5.39	4.9	4.65	5.76	5.73	6.08	5.29	5.06	5.91	5.94
$\sigma(c)$ / $\sigma(y)$	1.16	1.09	1.14	1.10	1.16	1.13	1.2	1.12	1.15	1.1
$\sigma(tb)/\sigma(y)$	0.66	0.61	0.67	0.64	0.65	0.64	0.74	0.69	0.63	0.73
$\rho(c,y)$	0.98	0.98	0.98	0.98	0.99	0.98	0.98	0.98	0.99	0.97
Welfare gains (%)		-0.06		-0.15		-0.08		-0.06		-0.02

The first two columns are obtained by setting γ^*=45, columns (3) and (4) are obtained by setting γ^*=35, columns (5) and (6) are obtained by setting γ^*=25, columns (7) and (8) are obtained by setting γ^*=15, and columns (9) and (10) are obtained by setting γ^*=5. Welfare gains row presents welfare gains obtained from switching from the ND economy to the FD economy.β^* is re-calibrated to match the S2S (hidden) debt/GDP ratio under scenarios in which $\gamma^* = 25$, $\gamma^* = 15$, $\gamma^* = 5$ and set to 0.923, 0.93 and 0.935, respectively.

A.4 The model without Nash-bargaining

In this section, we disable the Nash-bargaining process to investigate the role of the debt renegotiation scheme in the manuscript. We assume a constant recovery rate, $\alpha = 0.63$, for the model presented in Section 3.1.1. Specifically, equation (12) as well as the pricing equations become:

$$\begin{aligned} V^d\left(b, b_c, s\right) = & \; u\left(y - \phi(y) - \kappa b_c\right) \\ & + \beta\, \mathbb{E}_{s'|s}\left[\psi\, V\left(\alpha b(1+r^*), (1-\kappa_c) b_c (1+r^*), s'\right)\right. \\ & \left. + (1-\psi)\, V^d\left(b(1+r^*), (1-\kappa_c) b_c (1+r^*), s'\right)\right] \end{aligned} \tag{A.1}$$

$$(1+r^*) q\left(b', b'_c, s\right) = \mathbb{E}_{s'|s}\left\{\left[(1-d')\left[(1-\delta)q' + \kappa\right] + d' q'_d\right]\right\}, \tag{A.2}$$

$$q_d\left(b', b'_c, s\right) = \mathbb{E}_{s'|s}\left\{\left[\psi\, \alpha\left((1-d')\left[(1-\delta)q' + \kappa\right] + d' q'_d\right) + (1-\psi) q'_d\right]\right\}. \tag{A.3}$$

The main results, IRFs, and welfare decomposition are included below. Our qualitative results in the manuscript remain almost the same for portfolio dynamics, spreads, defaults, and consumption volatility.

The benchmark (ND) model returns a non-state contingent debt to GDP ratio slightly below 30 percent which is roughly equal to the long-term average of external debt to GDP ratio in Bolivia. Hidden debt to GDP ratio is estimated around 8.2 percent of GDP, which is the share of hidden debt in total external debt, approximated by Horn et al. (2021). The sovereign spread averages 241 basis points, which roughly matches its empirical counterpart. Overall, the model does a fairly good job in matching the empirical moments. The FD economy, similar to the model with endogenous bargaining, features more of non-contingent debt and less of S2S debt. With the higher non-contingent debt in the FD economy, the borrower is now more likely to default with higher spreads on the debt.

In regards to the IRFs in Figure A.2, switching to the FD economy allows the sovereign to internalize the negative effects of higher S2S debt on bond prices and results in a shift from S2S debt towards non-state contingent debt as in the manuscript.

The level of consumption decreases by about 0.2 percent on impact of the change to the FD economy. However, consumption quickly recovers and reaches to levels similar to the ND economy.

An important reason for the initial decline in consumption is the deleveraging the sovereign goes through in the first few years of the transition. As the hidden debt gradually declines to its new steady-state level, the sovereign faces lower prices for the non-contingent debt in the FD economy, where the level of hidden debt is fully revealed. This is also reflected in the initial spike in the average spread of non-contingent debt. The increase in spreads increases the cost of rolling over the non-contingent debt, decreases the level and volatility of consumption in the initial years of the transition. However, as hidden debt gradually declines, the cost of debt issuance declines and the level and volatility of consumption slowly recover and eventually reaches levels slower than its average in the ND economy.

As the re-balancing of the portfolio happens, the level of non-contingent debt increases, which causes an increase in default rates, which is also reflected in the evolution of spreads. Welfare follows the path of consumption. On impact, welfare is lower in the FD economy. However, it quickly recovers and reaches higher welfare after a few years along the transition. Table A.5 provides a decomposition of the welfare loss observed initially when the borrower made the switch from ND to the FD economy.

Table A.4: Long-run Statistical Moments

	Data	ND	FD
Targeted moments			
Non-contingent debt/GDP (%)	30.23	28.24	31.21
S1S (hidden) debt/GDP (%)	8.20	8.20	5.29
Mean spread, $E(R_s)$(%)	2.48	2.41	2.66
Duration, years	3	3.05	3.03
Non-targeted moments			
Default rate (%)	5	4.81	5.13
$\sigma(c)$ / $\sigma(y)$	1.22	1.28	1.22
$\sigma(tb)/\sigma(y)$	0.51	0.99	0.87
$\rho(c,y)$	0.81	0.98	0.98

Notes: ND and FD stand for nondisclosure and full disclosure, respectively. Same parameters are kept, except that we set $\alpha = 0.63$.

Table A.5: Decomposition of welfare gains at the time of switch

Welfare gain from cons. paths (%)	-0.025
From tilting consumption (%)	-0.010
From lowering income cost of defaulting (%)	-0.020
From lowering consumption volatility (%)	0.005

Notes: The table shows the decomposition of average welfare changes at the time of switch from the ND economy to the FD economy. The welfare calculations follow the methodology presented in Aguiar et al. (2020). See Appendix A.2 for more details.

A.5 Numerical Approximation Algorithm

The computational algorithm used in this paper requires iterating on the value and price functions until a convergence criteria of 10^{-5} is obtained. Functions are evaluated at equally spaced grid points. When evaluations fall outside of the grids, we approximate our functions by linear interpolation. For non-state contingent debt b, S2S debt b^c and income y, 40 grid points are used, whereas we utilize 300 Gauss-Legendre quadrature points to evaluate expectations over income into the subsequent period.[20]

1. Initial guesses of v^r, v^d, q and α are set at the their corresponding levels in a finite-horizon FD economy as follows:

[20] Önder (2023) elaborate the dominance of black-box optimizers over discretizing the state space with taste shocks while approximating value functions and price functionals for long-term debt. The previous version of the paper was using two-dimensional B-splines for approximations and our results do not change.

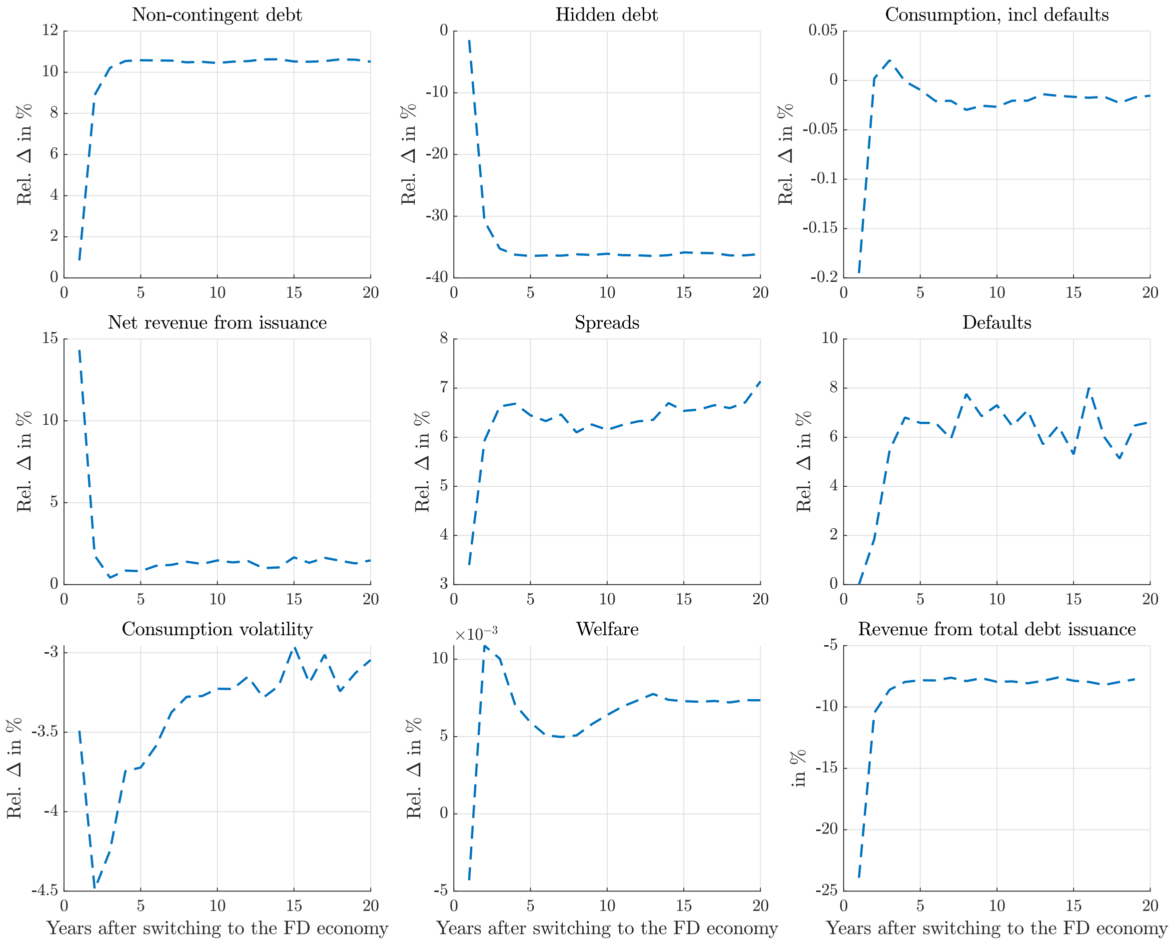

Figure A.2: Transitions from the ND economy to the FD economy: debt, default. and spread when hidden debt is collateralized. Net revenue from issuance is defined as $q \times (b' - (1-\delta)b) - \kappa b + q_c \times (b'_c - (1-\delta_c)b_c) - \kappa_c b_c$ whereas revenue from total debt issuance is defined as $q \times (b' - (1-\delta)b) + q_c \times (b'_c - (1-\delta_c)b_c)$

- $V^r(b, b^c, y, g) = u(y - \kappa b^c - \kappa b)$
- $V^d(b, b^c, y, g) = u(y - \phi(y) - \kappa b^c)$
- $q = 0$ and $\alpha = 0$

2. Optimization problem defined in equations (11) and (12) is solved for each grid point on bonds and income and then we search for a globally optimum point for next period's borrowing decisions. This requires generating 40 grid points for each of the portfolio components $b', b^{c'}$ to find maximizing candidates. Initially, for a fixed $b^{c'}$, we find the corresponding optimal grid for b'. We feed that particular grid point into one-dimensional DUVMIF routine of the IMSL library for FORTRAN as an initial guess to pinpoint the optimal b' for a fixed $b^{c'}$ with double precision. Finally, we feed our fixed $b^{c'}$ and the corresponding optimal b' into a two dimen-

sional optimization Powell routine to solve for the optimal portfolio $(b^{c'}, b')$ for each quadruple (b^c, b, y, g) coming out of our grids.

3. Iterate the procedure defined above for equations (11) to (13) until convergence criteria of 10^{-5} or lower is obtained.

4. If the convergence criteria is not attained, invoke local search methods within the neighborhood of the obtained candidate optima $(b^{c'}, b')$ for each grid points of (b^c, b, y, g) in the previous step.

5. Iterate the local search methods for equations (11) to (13) until convergence criteria of 10^{-5} is obtained.

The solution algorithm of the ND economy is similar to the FD economy, except that the price of non-contingent debt in the objective function under equation (16) is not a function of $b^{c'}$ anymore but a 5D array, $q^{ND}(b', b, b_c, y, g)$. We use linear interpolation to approximate it outside of grid points.

With the equilibrium value functions and pricing functionals as well as the decision rules for non-contingent debt borrowing, hidden debt borrowing and default, we simulate the model. In particular, we:

1. Set the number of samples $N = 250$, number of periods $T = 1501$ and $T_0 = 500$.

2. Use a random number generator to draw sequences of ε_t for $t = 1, 2, ..., T$ to compute the income of the subsequent periods and to evaluate the continuation value of default. We fix these drawn shocks to use them for each sample $n \in N$.

3. Set the initial endowment y and China's consumption growth g^* to be mean y and mean g^* and debt holdings b^c, b to be zero.

4. Cut the first T_0 periods of each sample before computing the moments of the simulation so that randomly chosen initial values will not have any influence on moments.

The moments reported in all tables are computed from the 500 simulated sample paths such that each sample includes 20 years without a default observation. The sample period begins at least 5 periods after regaining access to the credit markets following a default episode. Business cycle moments are reported after HP-detrending with a smoothing parameter of 100. We also make sure that both global search methods and local search methods generate very similar moments.