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Sudden stops, time inconsistency, and the duration of sovereign debt

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Abstract

We study the sovereign debt duration chosen by the government in the context of a standard model of sovereign default. The government balances off increasing the duration of its debt to mitigate rollover risk and lowering duration to mitigate the debt dilution problem. We present two main results. First, when the government decides the debt duration on a sequential basis, sudden stop risk increases the average duration by 1 year. Second, we illustrate the time inconsistency problem in the choice of sovereign debt duration: governments would like to commit to a duration that is 1.7 years shorter than the one they choose when decisions are made sequentially.

JEL Classification Numbers: F34, F41.

Keywords: sovereign debt, default, sudden stops, debt dilution, time inconsistency, debt maturity

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I. Introduction

We study the optimal duration of sovereign debt using a model of sovereign defaults à la Eaton and Gersovitz (1981) augmented to allow for long-term debt. This model allows us to capture a trade-off in sovereign debt management.[1] On the one hand, governments (particularly in emerging economies) are subject to significant rollover risk—i.e., governments face significant variations in the cost at which they can borrow. This indicates that it would be convenient for these governments to borrow using longer-term instruments. On the other hand, longer-term debt instruments strengthen the debt dilution problem (see Hatchondo et al., 2010b and the references therein). This problem arises because when the government borrows it does not internalize as a cost the effect of current borrowing decisions on the value of debt claims issued in prior periods. This induces the government to expand its borrowing and pay higher interest rates on its debt. If, instead, the government could commit to a path of borrowing levels, it would internalize how borrowing decisions undertaken t periods ahead affect borrowing opportunities between the current period and period t-1.[2] The debt dilution problem can also be mitigated by issuing shorter-term debt (Hatchondo and Martinez, 2009). In the extreme case in which the government only issues one-period bonds, current borrowing decisions cannot dilute debt because the government has already repaid its debt before any new debt is issued.

As Arellano and Ramanarayanan (2012), we study a model in which the government can issue both one-period bonds and bonds promising an infinite stream of coupon payments that decrease at the same constant rate. Thus, each period, by choosing the levels of one-period and long-term debt, the government chooses the duration of its debt. We use the calibration presented by Bianchi et al. (2012), which uses Mexico as a reference, and produce simulation results that replicate distinctive features of economies facing default risk: a high and countercyclical spread, a high consumption volatility, and a countercyclical trade balance.

We first show that the presence of sudden stops significantly increases the government's debt duration. The debt composition chosen in the economy without sudden stops implies an average duration of 4.5 years. The debt composition chosen in the economy with sudden stops implies an average duration of 5.4 years.[3]

We also investigate how the debt duration chosen by the government differs from the ex-ante optimal duration. We find that sudden stops also play a critical role in shaping the optimal ex-ante duration. The government prefers to commit to an average duration 0.8 years in the economy without sudden stops and to an average duration of 3.7 years in the economy with sudden stops.

[1] For a discussion of the relevant tradeoffs for choosing the optimal maturity of sovereign debt see Niepelt (2008) and Broner et al. (2013).

[2] Hatchondo et al. (2011) discuss how governments could gain from committing to debt ceilings.

[3] Durations are computed using the average spread in the simulations as a weighted average of the durations of short and long bonds, where the weight for each duration is given by the weight of each bond on the total debt level.

Our results indicate that the government would like to commit to a duration significantly shorter than the one it chooses sequentially. In the economy with sudden stops, the duration chosen by the government is almost 2 years longer than the one the government would like to commit to. Similarly, in the economy without sudden stops, the government chooses a duration that is on average almost 4 years longer than the one the government would like to commit to.

Why does the government choose a duration longer than the one to which it would like to commit? This occurs because of a time inconsistency problem similar to the debt dilution problem discussed above. The debt dilution problem increases the value of committing to a shorter debt duration that allows the government to pay a lower spread. However, when the government decides on a sequential basis, it does not internalize the effects that the debt duration chosen in a given period has on the borrowing opportunities available in previous periods. Therefore, the government typically chooses a duration longer than the optimal ex-ante duration. Our results cast doubt on the convenience of policies to increase the duration of sovereign debt for economies facing significant sovereign risk.

We add to the results presented by Arellano and Ramanarayanan (2012) and Hatchondo and Martinez (2009) by comparing the optimal durations with and without sudden stops, and comparing the durations the government chooses sequentially with the ex-ante optimal ones. They only consider model economies without sudden stops and do not compare the ex-ante optimal durations with the ones the government chooses when it makes decisions on a sequential basis.

Chatterjee and Eyigungor (2012) and Hatchondo et al. (2010b) present robustness exercises to their main results, indicating that one-period bonds are better than long-duration bonds in their benchmark economies because these economies do not have rollover crises. For a parameterization based on Argentina, Chatterjee and Eyigungor (2012) show that the government prefers bonds with a five years maturity over bonds with a one-quarter maturity when the probability of a self-fulfilling rollover crisis is high enough. Hatchondo et al. (2010b) show that the government prefers bonds with an average duration of 4.2 years over one-quarter bonds when the probability of a sudden stop is high enough. The results in this paper add to their insight by showing that even in economies where the government would want to commit to short-term debt, when it decides on a sequential basis, it chooses a debt composition with a significantly larger debt duration.

The rest of the article proceeds as follows. Sections II. and III. present the model and its calibration. Section IV. discusses how we solve the model. Results are presented in V.. Section VI. concludes.

II. Model

This section presents a dynamic small-open-economy model in which the government can issue non-state contingent defaultable debt of short and long maturity. The economy's endowment of the single tradable good is denoted by $y \in Y \subset \mathbb{R}_{++}$. This endowment follows a Markov process.

We consider a benevolent government that maximizes:

$$\mathbb{E}_t \sum_{j=t}^{\infty} \beta^{j-t} u\left(c_j\right),$$

where $\mathbb{E}$ denotes the expectation operator, β denotes the subjective discount factor, and c_t represents consumption of private agents. The utility function is strictly increasing and concave.

The timing of events within each period is as follows. First, the income and sudden-stop shocks (to be described below) are realized. After observing these shocks, the government chooses whether to default on its debt and makes its portfolio decision subject to constraints imposed by the sudden-stop shock and its default decision.

During a sudden stop, the government cannot issue new debt and suffers an income loss of $\phi^s\left(y\right)$. The government can buy back debt while in a sudden stop. Sudden stops intend to capture sharp reversals in capital flows that have been observed in emerging economies. A default model without sudden stops still features rollover risk but for standard calibrations cannot replicate the magnitude and frequency of the reversals in capital flows observed in the data. As in Bianchi et al. (2012), the sudden-stop shock follows a Markov process so that a sudden stop starts with probability $\pi \in [0,1]$ and ends with probability $\psi^s \in [0,1]$.

As in Arellano and Ramanarayanan (2012), we assume that the government can issue both one-period and long-duration bonds. A long-duration bond issued in period t promises an infinite stream of coupons that decrease at a constant rate δ. In particular, a long bond issued in period t promises to pay $(1-\delta)^{j-1}$ units of the tradable good in period $t+j$, for all $j \geq 1$. Hence, long-bond dynamics can be represented as follows:

$$b_{t+1}^L = (1-\delta)b_t^L + i_t^L,$$

where b_t^L is the number of long-bond coupons due at the beginning of period t, and i_t^L is the number of long bonds issued in period t.

Let b_t^S denote the number of short bonds at the beginning of period t. The budget constraint conditional on the government having access to credit markets is represented as follows:

$$c_t = y_t - b_t^S - b_t^L + b_{t+1}^S q_t^S + i_t^L q_t^L,$$

where q_t^M is the price of a bond of maturity $M \in \{S, L\}$, which in equilibrium depends on the exogenous shocks and the policy pair (b_{t+1}^S, b_{t+1}^L).

When the government defaults, it does so on all current and future debt obligations. This is consistent with the observed behavior of defaulting governments and it is a standard assumption in the literature.[4] As in most previous studies, we also assume that the recovery rate for debt in default (i.e., the fraction of the loan lenders recover after a default) is zero.[5]

A default event triggers exclusion from credit markets for a stochastic number of periods. Income is given by $y - \phi^d(y)$ in every period in which the government is excluded from credit markets because of a default. Thus, as in Bianchi et al. (2012), the income level of an economy in default is independent of whether the economy is facing a sudden stop. This implies that the income loss triggered by a default is effectively lower for an economy facing a sudden stop (since the sudden-stop income would be $y - \phi^s(y)$ in case the government repays). This assumption is justified because the income losses during both defaults and sudden stops intend to capture local disturbances caused by the loss of access to international credit markets. This assumption also allows the model to capture that some but not all sudden stops trigger defaults. The government does not have access to debt markets in the default period and then regains access to debt markets with constant probability $\psi^d \in [0, 1]$.

Foreign investors are risk-neutral and discount future payoffs at the rate r. Bonds are priced in a competitive market inhabited by a large number of identical lenders, which implies that bond prices are pinned down by a zero-expected-profit condition.

The government cannot commit to future (default and borrowing) decisions. Thus, one may interpret this environment as a game in which the government making decisions in period t is a player who takes as given the (default and borrowing) strategies of other players (governments) who will decide after t. We focus on Markov Perfect Equilibrium. That is, we assume that in each period the government's equilibrium default, borrowing, and saving strategies depend only on payoff-relevant state variables.

A. Recursive Formulation

We now describe the recursive formulation of the government's optimization problem. The sudden-stop shock is denoted by s, with $s = 1$ ($s = 0$) indicating that the economy is (is not) in a sudden-stop.

Let V denote the value function of a government that is not currently in default. For any bond price function q, the function V satisfies the following functional equation:

$$V(b^S, b^L, y, s) = \max\left\{V^R(b^S, b^L, y, s), V^D(y, s)\right\}, \tag{1}$$

[4] Sovereign debt contracts often contain an acceleration clause and a cross-default clause. The first clause allows creditors to call the debt they hold in case the government defaults on a debt payment. The cross-default clause states that a default in any government obligation constitutes a default in the contract containing that clause. These clauses imply that after a default event, future debt obligations become current.

[5] Yue (2010) and Benjamin and Wright (2008) present models with endogenous recovery rates.

where the government's value of repaying is given by

$$V^R(b^S, b^L, y, s) = \max_{b^{S\prime}\geq 0, b^{L\prime}\geq 0, c\geq 0} \left\{u\left(c\right) + \beta \mathbb{E}_{(y',s')|(y,s)} V(b^{S\prime}, b^{L\prime}, y', s')\right\} \tag{2}$$

subject to

$$c = y - s\phi^s\left(y\right) - b^S - b^L + q^S(b^{S\prime}, b^{L\prime}, y, s)b^{S\prime} + q^L(b^{S\prime}, b^{L\prime}, y, s)\left[b^{L\prime} - (1-\delta)b^L\right],$$

and if $s = 1$, $b^{L\prime} - (1-\delta)b^L \leq 0$, and $b^{S\prime} = 0$.

The value of defaulting is given by:

$$V^D(y, s) = u\left(y - \phi^d(y)\right) + \beta \mathbb{E}_{(y',s')|(y,s)}\left[(1-\psi^d)V^D(y', s') + \psi^d V(0, 0, y', s')\right]. \tag{3}$$

The solution to the government's problem yields decision rules for default $\hat{d}$, one-period debt $\hat{b}^S$, long-term debt $\hat{b}^L$, and consumption $\hat{c}$. The default rule $\hat{d}$ is equal to 1 if the government defaults, and is equal to 0 otherwise.

In a rational expectations equilibrium (defined below), investors use these decision rules to price debt contracts. Because investors are risk neutral, the bond-price functions solve the following functional equations:

$$q^S(b^{S\prime}, b^{L\prime}, y, s)(1+r) = \mathbb{E}_{(y',s')|(y,s)}\left[1 - \hat{d}(b^{S\prime}, b^{L\prime}, y', s')\right] \tag{4}$$

and

$$q^L(b^{S\prime}, b^{L\prime}, y, s)(1+r) = \mathbb{E}_{(y',s')|(y,s)}\left[1 - \hat{d}(b^{S\prime}, b^{L\prime}, y', s')\right]\left[1 + (1-\delta)q(b^{S\prime\prime}, b^{L\prime\prime}, y', s')\right], \tag{5}$$

where $b^{S\prime\prime} = \hat{b}^S(b^{S\prime}, b^{L\prime}, y', s')$ and $b^{L\prime\prime} = \hat{b}^L(b^{S\prime}, b^{L\prime}, y', s')$.

Equations (4) and (5) indicate that in equilibrium, an investor has to be indifferent between selling a government bond today and investing in a risk-free asset, and keeping the bond and selling it next period. If the investor keeps a one-period bond and the government does not default in the next period, he receives a payment of one unit. If the investor keeps a long-term bond and the government does not default in the next period, he first receives a one unit coupon payment and then sells the bond at market price, which is equal to $(1-\delta)$ times the price of a bond issued next period.

B. Recursive Equilibrium

A *Markov Perfect Equilibrium* is characterized by

1. a set of value functions V, V^R and V^D,
2. rules for default $\hat{d}$, borrowing $\hat{b}^S$ and $\hat{b}^L$, and consumption $\hat{c}$,
3. and bond price functions q^S and q^L,

such that:

i. given bond price functions q^S and q^L; the policy functions $\hat{d}$, $\hat{b}^S$, $\hat{b}^L$, $\hat{c}$, and the value functions V, V^R, V^D solve the Bellman equations (1), (2), and (3).

ii. given policy rules $\hat{d}$, $\hat{b}^S$, and $\hat{b}^L$; the bond price functions q^S and q^L satisfy equations (4) and (5).

III. Calibration

The utility function displays a constant coefficient of relative risk aversion, i.e.,

$$u\left(c\right)=\frac{c^{1-\gamma}-1}{1-\gamma},\text{ with }\gamma\neq 1.$$

The endowment process follows:

$$\log(y_t)=\left(1-\rho\right)\mu+\rho\log(y_{t-1})+\varepsilon_t,$$

with $|\rho|<1$, and $\varepsilon_t\sim N\left(0,\sigma_\epsilon^2\right)$.

As in Arellano (2008), we assume an asymmetric cost of default $\phi^d\left(y\right)$, so that it is proportionally more costly to default in good times. This is a property of the endogenous default cost in Mendoza and Yue (2012). Chatterjee and Eyigungor (2012) shows that this property allows the equilibrium default model to match the behavior of the spread in the data. In particular, we assume a quadratic loss function for income during a default episode $\phi^d\left(y\right)=d_0y+d_1y^2$, as in Chatterjee and Eyigungor (2012). As in Bianchi et al. (2012), we assume that the income loss during a sudden stop is a fraction of the income loss after a default: $\phi^s\left(y\right)=\lambda\phi^d\left(y\right)$.

Table 1 presents the benchmark values given to all parameters in the model. A period in the model refers to a quarter. The coefficient of relative risk aversion is set equal to 2, and the risk-free interest rate is set equal to 1 percent. These are standard values in quantitative business cycle and sovereign default studies.

The average duration of sovereign default events is three years ($\psi^d=0.083$), in line with the duration estimated in Dias and Richmond (2007). We study economies with and without sudden stops. In the economies with sudden stops, there is one sudden stop every 10 years, in line with the frequency estimated by Bianchi et al. (2012) and Jeanne and Ranciere (2011). We set ψ^s to match the duration of sudden stops in the data. We assume $\psi^s=0.25$ to have an average duration of sudden stops of one year, which is consistent with the estimations of Bianchi et al. (2012) and Forbes and Warnock (2012).

We assume $\delta=0.03\%$. We will show that this implies a debt duration comparable to those observed in the data.[6]

[6] We use the Macaulay definition of duration that, with the coupon structure in this paper, is given by $D=\frac{1+r^*}{\delta+r^*}$, where r^* denotes the constant per-period yield delivered by the bond. Note that the one-period bond is equivalent to a long bond with $\delta=1$ and thus has a duration equal to 1 period.

Table 1: Benchmark parameter values.

Risk aversion	γ	2
Risk-free rate	r	1%
Probability default exclusion ends	ψ^d	0.083
Probability of sudden-stop exclusion ends	π	0.025
Probability of reentry after sudden stop	ψ^s	0.25
Debt duration	δ	0.03
Income autocorrelation coefficient	ρ	0.94
Standard deviation of innovations	σ_ϵ	1.5%
Mean log income	μ	$(-1/2)\sigma_\epsilon^2$
Discount factor	β	0.9745
Income cost of defaulting	d_0	-1.01683
Income cost of defaulting	d_1	1.18961
Income cost of sudden stops	λ	0.5

The parameter values that govern the endowment process, the level of debt, and the mean and standard deviation of the spread are taken from Bianchi et al. (2012), who calibrate these values using Mexico as a reference. They calibrate the value of the discount factor β, the parameters of the income cost of defaulting d_0 and d_1, and the parameter determining the relative income cost of a sudden stop compared with a default λ targeting an average debt-to-GDP ratio of 43 percent, a mean spread of 3.4 percent, a spread standard deviation of 1.5 percent, and an average accumulated income cost of a sudden stop of 14 percent of annual income. We obtain values similar to these targets with our benchmark model. Thus, these parameter values are still reasonable for our purposes.

In order to compute the sovereign spread implicit in a bond price, we first compute the yield i an investor would earn if it holds the bond to maturity (forever in the case of our long bonds) and no default is ever declared. This yield satisfies

$$q_t^M = \frac{1}{(1+i)} + \sum_{j=1}^{\infty} \frac{(1-\delta)^j}{(1+i)^{j+1}},$$

where $\delta = 1$ for one-period bonds. The sovereign spread is the difference between the yield i and the risk-free rate r. We report the annualized spread

$$r_t^s = \left(\frac{1+i}{1+r}\right)^4 - 1.$$

Debt levels in the simulations are calculated as the present value of future payment obligations discounted at the risk-free rate, i.e., $b_t^M(1+r)(\delta+r)^{-1}$, where $\delta = 1$ for one-period bonds. We report debt levels as a percentage of annualized income.

IV. Computation

The recursive problem is solved using value function iteration. The approximated value and bond price functions correspond to the ones in the first period of a finite-horizon economy with a number of periods large enough to make the maximum deviation between the value and bond price functions in the first and second period smaller than 10^{-6}. We solve the optimal portfolio allocation in each state by searching over a grid of debt levels and then using the best portfolio on that grid as an initial guess in a nonlinear optimization routine. The value functions V^D and V^R and the bond price functions q^S and q^L are approximated using linear interpolation over y and cubic spline interpolation over debt levels.[7] We use 20 grid points for one-period and long-term debt, and 25 grid points for income realizations. Expectations are calculated using 50 quadrature points for the income shock.

V. Results

We first show that the simulations of the benchmark model match features of emerging economies reasonably well. We then show how the presence of sudden stops increases the debt duration chosen by the government. In addition, we calculate the optimal ex-ante debt duration. We show how the optimal ex-ante duration is also influenced by the presence of sudden stops. Furthermore, a government that chooses the debt composition in each period ends up choosing debt durations that are longer than the ex-ante optimal duration.

A. The effect of sudden stops on debt duration

Table 2 reports moments in the simulations of the benchmark model (with sudden stops). The table shows that the simulations match features of emerging economies reasonably well (Durdu, 2013 surveys the literature on business cycles fluctuations in emerging economies). For instance, the simulations produce a high and countercyclical spread, a consumption process that is more volatile than the income process, and a countercyclical trade balance. The countercyclicality of the trade balance reflects the government's choice of reducing its borrowing in periods with low income. When current income is low, lenders anticipate that income realizations and, thus, the cost of defaulting are likely to be low in future periods. Consequently, for any debt level, lenders ask for a higher interest rate. This lead the government to choose less borrowing.

Table 2 also quantifies the role of sudden stops on the debt duration chosen by the government. The table shows that the debt duration declines almost by one year in the absence of sudden stops ($\pi = 0$). With a shorter duration, the debt dilution problem is mitigated and, therefore, the average spread is lower than the one observed in the

[7] Hatchondo et al. (2010a) discuss the advantages of using interpolation and solving for the equilibrium of a finite-horizon economy.

Table 2: Simulation results

	With sudden stops	Without sudden stops
Average duration (years)	5.4	4.5
Mean Long-Debt-to-GDP	39.7	29.7
Mean Short-Debt-to-GDP	0.0	9.7
Mean Long-Debt r_s	3.0	1.6
Mean Short-Debt r_s	na	1.5
Long-Debt $\sigma(r_s)$	1.7	1.0
Short-Debt $\sigma(r_s)$	na	5.7
$\sigma(c)/\sigma(y)$	1.5	1.4
$\sigma(tb)$	1.3	1.9
$\rho(tb, y)$	-0.9	-0.5
$\rho(c, y)$	0.99	0.93

Note: The standard deviation of x is denoted by $\sigma(x)$. The coefficient of correlation between x and z is denoted by $\rho(x, z)$. Moments are computed using detrended series. Trends are computed using the Hodrick-Prescott filter with a smoothing parameter of $1,600$. Moments for the simulations correspond to the mean value of each moment in 250 simulation samples, with each sample including 120 periods (30 years) without a default episode. Samples start at least five years after a default. Consumption and income are expressed in logs.

benchmark economy (see, for instance, Hatchondo and Martinez, 2009). Notice also that the change in duration does not significantly affect the level of nominal debt obligations.

B. The optimal ex-ante debt duration

The previous subsection presented results for the case in which the government decides the debt duration on a sequential basis. In this Subsection we study the preferred duration when the government can commit to a given duration. As in Hatchondo and Martinez (2009), we find the preferred ex-ante debt duration by solving the model for different values of δ. In order to save on computational time, we assume in this Subsection that the government can only issue long-term bonds (i.e., we assume $b^S = 0$). We then look for the optimal value of δ in the initial period.

Figure 1 presents ex-ante welfare for different debt durations. We measure ex-ante welfare as the continuation value that follows from a state with zero debt and an income level equal to the unconditional mean. The optimal δ for the economy with sudden stops is 0.056 (implying a duration of 3.7 years) and the optimal δ for the economy without sudden stops is 0.29 (implying a duration of 0.8 years).

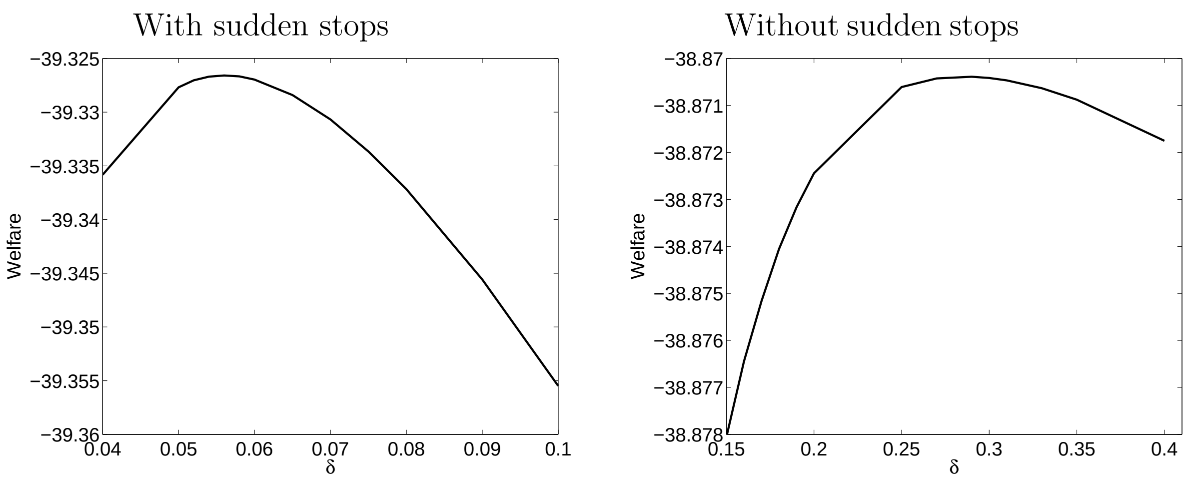

Figure 1: Value function V evaluated at a state with no debt and with income equal to the unconditional mean. The left panel corresponds to an economy with sudden stops. The right panel corresponds to an economy without sudden stops.

Figure 2 illustrates the effects of debt duration on consumption volatility and the spread. On the one hand, for a given debt level, a shorter debt duration implies larger debt obligations and, thus, a larger consumption fall when the borrowing cost increases (either because aggregate income falls or a sudden stop shock hits the economy). On the other hand, a shorter debt duration mitigates the debt dilution problem and helps reducing the interest rate spread (see Hatchondo et al. (2010b)).

Table 3 reports moments in the model simulations with and without sudden stops,

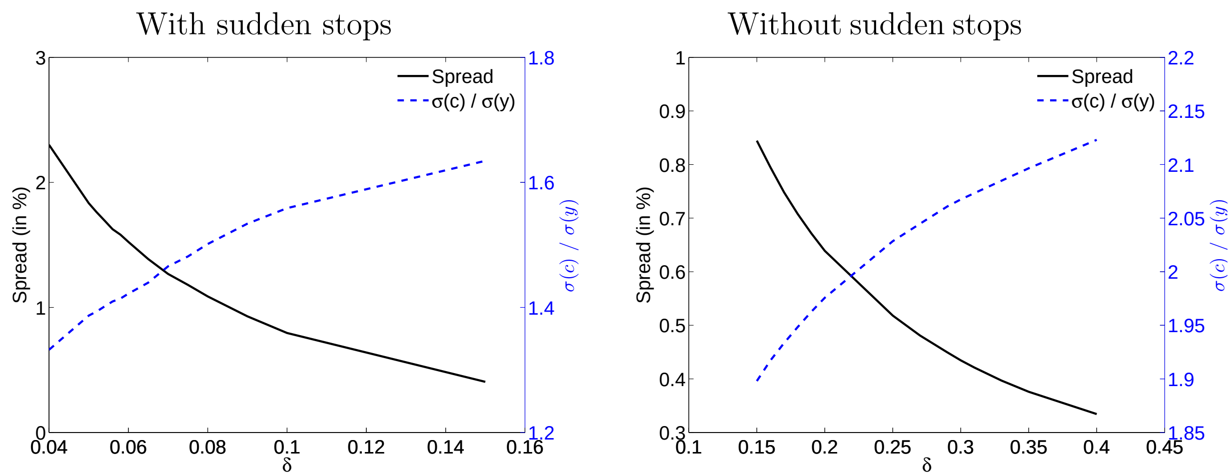

Figure 2: Spread and consumption volatility for different debt durations. The left panel corresponds to an economy with sudden stops. The right panel corresponds to an economy without sudden stops.

assuming the optimal value of δ for each case. As in Table 2, since a shorter duration mitigates the debt dilution problem, it implies significantly lower spreads even though the debt level does not experience a significant decline.

More interestingly, comparing Tables 2 and 3 indicates that in the economies with and without sudden stops the optimal ex-ante debt duration is shorter than the duration the government chooses sequentially. This occurs because of a time inconsistency problem similar to the debt dilution problem. As discussed in the introduction, the debt dilution problem increases the value of committing to a shorter debt duration as it allows the government to pay a lower spread. However, when the government decides on a sequential basis, it does not internalize the effect that the debt composition at the beginning of a given period has on the borrowing terms faced in previous periods. Therefore, the government typically chooses a duration longer than the one it would like to commit to in the initial state.

VI. Conclusions

We present two main results in the paper. First, we quantify the role that sudden stops have on the preferred duration of sovereign debt. Second, we illustrate the time inconsistency problem in the choice of sovereign debt duration: governments would like to commit to a duration shorter than the one they choose when they make decisions sequentially. Our results cast doubt on the convenience of policies to increase the duration of sovereign debt for economies facing significant sovereign risk.

Table 3: Simulation Results when the government commits to a debt duration

	With sudden stops	Without sudden stops
Average duration (years)	3.6	0.8
Mean Debt-to-GDP	34.4	34.8
Mean r_s	1.7	0.5
$\sigma(r_s)$	1.2	0.7
$\sigma(c)/\sigma(y)$	1.8	2.1
$\sigma(tb)$	2.2	2.2
$\rho(tb, y)$	-0.3	-0.7
$\rho(c, y)$	0.76	0.91

Note: The standard deviation of x is denoted by $\sigma(x)$. The coefficient of correlation between x and z is denoted by $\rho(x, z)$. Moments are computed using detrended series. Trends are computed using the Hodrick-Prescott filter with a smoothing parameter of $1,600$. Moments for the simulations correspond to the mean value of each moment in 250 simulation samples, with each sample including 120 periods (30 years) without a default episode. Samples start at least five years after a default. Consumption and income are expressed in logs.

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