Sovereign Cocos

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Abstract

We study a model of equilibrium sovereign default in which the government issues cocos (contingent convertible bonds) that stipulate a suspension of debt payments when the government faces liquidity shocks in the form of an increase of the bondholders' risk aversion. We find that in spite of reducing the frequency of defaults triggered by liquidity shocks, introducing cocos increases the overall default frequency. By mitigating concerns about liquidity, cocos make indebtedness and default risk more attractive for the government. In contrast, cocos that stipulate debt forgiveness when the government faces the shock, achieve larger welfare gains by reducing default risk.

1 Introduction

The European debt crisis revived discussions about policies to mitigate the likelihood and the costs of sovereign debt crises. The reprofiling of sovereign debt plays a central role in these discussions, where reprofiling refers to extending the maturity of debt instruments or imposing a debt service standstill when the government faces adverse "liquidity" shocks. Most proposals entail governments issuing "cocos" (contingent convertible bonds) or "extendible" bonds with a trigger clause that allows a reprofiling of debt payments without causing a credit event (Barkbu et al., 2012; Brooke et al., 2011; Buiter and Sibert, 1999; Consiglio and Zenios, 2015; IMF, 2017a; IMF, 2017b; Weber et al., 2011). A commonly discussed liquidity shock that would trigger reprofiling is an increase in the government's funding cost.[1] Ideally, the trigger for reprofiling would be closely tied to the government's repayment capacity but would not be manipulable by the government.

Critics of these proposals claim that cocos would ultimately increase the likelihood of debt crises and hurt the sovereign (FT, 2013, 2014). One argument against cocos is that if the triggering of maturity-extending clauses becomes more likely, creditors would scramble out of the market, triggering a liquidity crisis.

This paper presents a formal quantitative analysis of sovereign cocos. Would cocos reduce or increase the frequency of crises and the sovereign spreads paid by the government? Would they benefit the government? Should the reprofiling mandated by cocos be accompanied by face-value haircuts?

We measure the effects of cocos using a quantitative sovereign default framework à la Eaton and Gersovitz (1981) (Aguiar and Gopinath, 2006; Arellano, 2008). We augment the baseline

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[1]See Barkbu et al. (2012), Consiglio and Zenios (2015), IMF (2017a), and IMF (2017b). Some proposals also discuss the sovereign receiving "liquidity" (and not "solvency") assistance from the official sector as a trigger for reprofiling (Brooke et al., 2011; IMF, 2014; Weber et al., 2011). In the 2014 review of its lending framework (IMF, 2014), the IMF discusses that "in circumstances where a member has lost market access and debt is considered sustainable but not with high probability, the Fund would be able to provide exceptional access on the basis of a debt operation that involves an extension of maturities (normally without any reduction of principal or interest)." IMF (2014) also explains that "in circumstances where a member's debt is unsustainable, a reprofiling would be inappropriate and an upfront debt reduction operation would be pursued". To prevent liquidity crises, Buiter and Sibert (1999) propose a Universal Debt Rollover Option entitling (both private and sovereign) borrowers to extend performing debt for a specified period at a penalty rate.

model with the a shock to the lenders' risk aversion, a "liquidity" shock commonly mentioned as a possible trigger of reprofiling in policy discussion (IMF, 2017a).[2] Formally, we analyze a small open economy that receives a stochastic endowment stream of a single tradable good. At the beginning of each period, the government observes the endowment and risk-premium shocks, and decides whether to default. A defaulting government suffers a utility loss and cannot borrow. A government that does not default can issue sovereign bonds that are priced by competitive foreign investors. In the baseline model, the government issues only non-contingent bonds. In the cocos model, the government can also issue cocos for which payments are suspended in periods with an adverse risk-premium shock. We quantify the effects of cocos by comparing simulations of the cocos model with the ones obtained when the government can only issue non-contingent debt.

We find that as argued by proponents of sovereign cocos, cocos reduce the frequency of sovereign defaults triggered by liquidity shocks and generate welfare gains. However, as argued by critics of cocos, cocos increase the overall frequency of sovereign defaults. This occurs because when cocos are available, the government chooses higher debt levels. By mitigating concerns about liquidity, cocos make indebtedness and thus default risk more attractive. Cocos also augment the increase in spreads triggered by adverse liquidity shocks because (i) lenders dislike a suspension of payments triggered by risk-premium shocks (unless this suspension of payments greatly reduces the probability of default), and (ii) the suspension of payments triggered by financing shocks leads to an increase of debt levels while the government faces these shocks.

We also find that the postponement of debt payments triggered by cocos does not provide sufficient debt relief: The government obtains larger welfare gains if the reprofiling of debt payments is accompanied by face-value haircuts (i.e., by debt forgiveness). Haircuts lower default risk, decreasing not only the average spread but also the spread increase triggered by the liquidity shock. This occurs because while debt levels increase when cocos only postpone debt payments, debt levels decline when cocos trigger debt relief.

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[2]We find equivalent results when we model other shocks that trigger debt relief, including shocks to the government's financing needs. We present those results in Appendix A.

Related literature. Sovereign cocos are only part of the set of state-contingent debt instruments for sovereigns discussed in both academic and policy circles. IMF (2017a) and IMF (2017b) distinguish between debt instruments with continuous adjustment of debt service payments, including GDP-linked bonds, and those involving discrete adjustment, including the cocos studied in this paper. Contingent debt instruments are different in both the shock that triggers the contingency (e.g., GDP, terms of trade, global liquidity, natural disasters) and the effect of these shocks on payments (e.g., payment suspension and payment reduction). A thorough analysis of the merits and plausibility of different state contingencies is beyond the scope of this paper. We restrict attention to debt instruments that are currently at the center of policy debates and evaluate these instruments using a model with plausible quantitative predictions.

Hatchondo and Martinez (2012), Hatchondo et al. (2016), and Önder (2021) show that in the default model, issuing bonds linked to aggregate income allows the government to lower default risk while increasing the average level of borrowing. Hatchondo et al. (2016) also show that bonds with payments indexed to either the level of debt or the sovereign spread can produce welfare gains and reduce default risk. Here, in contrast, we show that default risk may increase with cocos that suspend debt payments.

Borensztein et al. (2017), Mallucci (2020), and Phan and Schwartzman (2021) study disaster risk. Borensztein et al. (2017) discuss welfare gains from introducing catastrophe bonds in a complete market model with two states of the world. Mallucci (2020) find that in a default model, disaster risk and climate change reduce the government's debt-carrying capacity and that "disaster clauses" that provide debt-servicing relief would allow governments to borrow more but may reduce welfare. Phan and Schwartzman (2021) find that the risk of default amplifies and propagates the damage caused by natural disasters and that welfare gains from catastrophe bonds are only a small fraction of the welfare losses from the increased risk of natural disasters.

In models in which debt is not defaultable, Caballero and Panageas (2008) and Jeanne and Ranciere (2011) study insurance contracts against changes in the probability and the occurrence of sudden stops. Borensztein et al. (2013), Lopez-Martin et al. (2019) and Ma and Valencia (2017) discuss welfare gains from using instruments that provide insurance against fluctuations in the price of exports. Önder et al. (2022) model and document suspension of debt payments

for firms in Colombia because of COVID-19.

Aguiar et al. (2019), Dvorkin et al. (2020) and Mihalache (2020) analyze the trade offs between using extensions of maturity or haircuts in sovereign debt restructurings. Dvorkin et al. (2020) discuss a regulatory cost of haircuts that help them account for the extensions of maturity during restructurings observed in the data. To the extent these costs could explain why existing proposals for sovereign cocos ignore the advantages of haircuts we find in this paper, our findings could be interpreted as a measure of the inefficiencies in the design of sovereign cocos generated by these costs.

Hatchondo et al. (2020b) find that haircuts are part of the optimal one-time unanticipated debt relief in response to a one-time large unanticipated shock like COVID-19 (in contrast, we study the optimal ex-ante design of debt instrument to respond to anticipated shocks). In their setup, haircuts are useful because the large shock leads to debt overhang: reducing the stock of debt through haircuts increases the market value of the debt stock (Hatchondo et al., 2014). In contrast, in the simulations of our model, there is no debt overhang after liquidity shocks.

Fernández and Martin (2015) study sovereign debt reprofiling in a three-period model with a fixed initial debt level in which debt restructurings (including reprofilings) can avoid costly liquidations. They show that a restructuring that does not decrease expected payments to creditors during crises improves ex-ante welfare.

The rest of the paper proceeds as follows. Section 2 introduces the model. Section 3 discusses the benchmark calibration. Section 4 discusses the effects of introducing cocos with payments postponed in periods of high risk premium. Section 5 shows that the government benefits when cocos deliver additional debt relief through haircuts. Section 6 concludes.

2   The model

This section presents a dynamic small-open-economy model in which the government can issue both non-state-contingent debt and cocos. 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 and borrowing strategies depend only on payoff-relevant state variables.

Within each period, the timing of events is as follows. First, the endowment and risk-premium shocks are realized. After observing these shocks, the government chooses whether to default on its debt and borrows subject to constraints imposed by its default decision.

The economy's endowment of the single tradable good is denoted by $y \in Y \subset \mathbb{R}_{++}$. The endowment process follows

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

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

The bondholders' risk-premium shock $p_t \in \{p_L, p_H\}$ follows a Markov process such that a high-risk-premium episode starts with probability $\pi_{LH}(y) \in [0, 1]$ and ends with probability $\pi_{HL} \in [0, 1]$. To capture the fact that negative conditions in international capital markets coincide with low domestic aggregate income (Calvo et al., 2004; Calvo et al., 2006), we assume that π_{LH} is a decreasing function of y: $\pi_{LH}(y) = Min\left\{\pi_{LH0} e^{-\pi_{LH1} \log(y) - 0.5\pi_{LH1}^2 \sigma_\varepsilon^2}, 1\right\}$.

The price of sovereign bonds satisfies a no-arbitrage condition with stochastic discount factor $M(y', y, p) = exp(-r - p\varepsilon' - 0.5p^2\sigma_\varepsilon^2)$, where r denotes the risk-free rate at which lenders can borrow or lend. This model of the discount factor is a special case of the discrete-time version of the Vasicek (1977) one-factor model of the term structure and has often been used in models of sovereign default (e.g., Arellano and Ramanarayanan, 2012; Bianchi et al., 2018).

Preferences of the government over private consumption are given by

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

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.

As Hatchondo and Martinez (2009), we assume that a non-contingent bond issued in period t promises an infinite stream of coupons that decrease at a constant rate δ. In particular, a bond

issued in period t promises to pay $\delta(1 - \delta)^{j-1}$ units of the tradable good in period $t + j$, for all $j \geq 1$. Hence, non-contingent debt dynamics can be represented as follows:

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

where δb_t are the payments due in period t, and i_t is the number of non-contingent bonds issued in period t.

Cocos promise an infinite stream of coupons that decrease at the constant rate δ_C, but also allow for bond payments to be suspended in periods with $p_t = p_H$. Creditors earn the rate r_C on suspended payments.

When the government defaults, it does so on current and future debt obligations. This is consistent with the observed behavior of defaulting governments and it is a standard assumption in the literature.[3] Following Hatchondo et al. (2016), we capture in a simple fashion the positive recovery rate of debt in default observed in the data. Starting from the first period after the government defaults, the government is presented with the opportunity to end the default with time-invariant probability ξ. In order to end the default, the government needs to exchange the bonds that are in default with bonds that promise to pay $\alpha < 1$ times the payments promised by the exchanged bonds. The government may choose to not restructure the debt and continue in default, in which case its debt level will still be α times the debt level before the restructuring opportunity (thus, the government can obtain a lower recovery rate at the expense of a longer default period). During default, the government's payment obligations grow at the interest rate r.

In a model with long-term debt, a positive recovery rate may give the government incentives to issue large amounts of debt before defaulting, which would allow for a large increase in consumption (Hatchondo et al., 2014). In order to avoid this problem, we assume that the government cannot issue bonds at a price lower than $\underline{q}$ (the secondary market price of government debt can still be lower than $\underline{q}$). We choose a value of $\underline{q}$ that eliminates consumption booms before

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[3]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.

defaults and is never binding in the simulations.

As Bianchi et al. (2018), we assume a defaulting government cannot borrow, suffers a one-time utility loss $U^D(y)$.[4] Also following Bianchi et al. (2018), we assume a fixed level of government expenditures $g > 0$. This allows us to capture rigidities in the government budget constraint that accentuate the importance of liquidity shocks.[5] Thus, if the government is not in default and cocos payments are suspended, consumption is given by

$$c = y - g - \delta b + q(b', b'_C, y, p, g) \left[b' - b(1 - \delta) \right] + q_C(b', b'_C, y, p, g) \left(b'_C - b_C e^{r_C} \right),$$

where q and q_C denote the price of non-contingent bonds and cocos, respectively. If cocos payments are not suspended, consumption is given by

$$c = y - g - \delta b + q(b', b'_C, y, p, g) \left[b' - b(1 - \delta) \right] + q_C(b', b'_C, y, p, g) \left[b'_C - b_C(1 - \delta_C) \right].$$

If the government defaults, consumption is given by $c = y - g$.

2.1 Recursive Formulation

Let $s \equiv (y, p)$ denote the vector of exogenous states. Let V denote the value function of a government that is not currently in default. The function V satisfies the following functional equation:

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

where the government's value of repaying is given by

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[4]In the calibration, a period in the model is a year and thus the exclusion from debt markets after defaulting lasts for a year, which is a common assumption in quantitative studies of sovereign default (Arellano, 2008; Bianchi et al., 2018), and is also within the range of empirical estimates (Gelos et al., 2011). Assuming a utility cost of defaulting instead of the also often used income cost allows us to calibrate the income process without using the simulations (because default does not affect aggregate income).

[5]Introducing rigidities in the government's budget constraint allows the default model to generate plausible adjustments in response to shocks (Bocola and Dovis, 2015). Rigidities also play an important role in policy analysis. For example, the IMF's debt sustainability analysis assumes that the government cannot adjust spending for two years in response to shocks to GDP or contingent liabilities (IMF, 2013).

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

subject to

$$c = y - g - \delta b - [1 - \mathcal{I}(p)] \, \delta_C b_C + q(b', b_C', s)i + q_C(b', b_C', s)i_C,$$

$$i = b' - b(1 - \delta),$$

$$i_C = b_C' - [1 - \mathcal{I}(p)] \, b_C(1 - \delta_C) - \mathcal{I}(p) b_C e^{r_C},$$

$$q(b', b_C', s) \geq \underline{q} \; \forall \; b' > b(1 - \delta),$$

$$q_C(b', b_C', s) \geq \underline{q} \; \forall \; b_C' > [1 - \mathcal{I}(p)] \, b_C(1 - \delta_C) + \mathcal{I}(p) b_C e^{r_C},$$

where $\mathcal{I}(p)$ is an indicator function that is equal to 1 if the risk premium shock p takes the high value, and is equal to 0 otherwise. The value of defaulting is given by:

$$V^D(b, b_C, s) = u\left(y - g\right) - U^D(y) + \beta \mathbb{E}_{s'|s} \left[V(\alpha b, \alpha b_C, s')\right]. \tag{3}$$

The price of non-contingent bonds is given by

$$q(b', b_C', s) \;\; = \;\; \mathbb{E}_{s'|s} \left[M(\varepsilon', p) \left[d' \alpha q\left(\alpha b', \alpha b_C', s'\right) (1 - d') \left[\delta + (1 - \delta)q\left(b'', b_C'', s'\right)\right]\right]\right], \tag{4}$$

and the price of a coco is given by

$$
\begin{aligned}
q_C(b', b_C', s) \;\; = \;\; & \mathbb{E}_{s'|s} \left[M(\varepsilon', p) \left[d' \alpha q_C\left(\alpha b', \alpha b_C', s'\right)\right.\right. \\
& + \;\; (1 - d') \left[\left[1 - \mathcal{I}(p', g')\right] \left[\delta_C + (1 - \delta_C)q_C\left(b'', b_C'', s'\right)\right]\right. \\
& + \;\; \left.\left.\left. \mathcal{I}(p', g')e^{r_C} q_C\left(b'', b_C'', s'\right)\right]\right]\right], \tag{5}
\end{aligned}
$$

where $d' = \hat{d}\left(b', b_C', s'\right)$ denotes the next-period equilibrium default decision, $b'' = \hat{b}\left(b', b_C', s'\right)$ denotes the next-period equilibrium non-contingent debt decision and $b_C'' = \hat{b}_C\left(b', b_C', s'\right)$ denotes the next-period equilibrium cocos decision.

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2.2 Recursive Equilibrium

A *Markov Perfect Equilibrium* is characterized by

1. rules for default $\hat{d}$, non-contingent borrowing $\hat{b}$, and cocos borrowing $\hat{b}_C$

2. and bond price functions q and q_C for non-contingent and cocos debt, respectively,

such that:

i. given the bond price functions q and q_C, the policy functions $\hat{d}$, $\hat{b}$, and $\hat{b}_C$ solve the Bellman equations (1), (2), and (3).

ii. given policy rules $\left\{ \hat{d}, \hat{b}, \hat{b}_C \right\}$, the bond price functions q and q_C satisfy conditions (4) and (5), respectively.

3 Calibration for the economy without cocos

We first calibrate the benchmark model without cocos ($i_C = 0$) to match salient features of emerging economies (and other economies facing default risk). The calibration strategy follows closely the one presented by Bianchi et al. (2018).

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

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

Following Bianchi et al. (2018), the utility cost of defaulting is given by $U^d\left(y\right) = \max\{0, \lambda_0 + \lambda_1 y\}$. As explained by Hatchondo and Martinez (2017), having two parameters in the cost of defaulting allows us to match the average levels of debt and spread in the data.

Table 1 presents the benchmark values given to all parameters in the model. A period in the model refers to a year. The risk-free interest rate is set equal to 4 percent, and the discount factor β is set equal to 0.92. These are standard values in quantitative studies of sovereign defaults and business cycles in small open economies. We set $\underline{q} = 0.45$, which eliminates consumption booms before defaults and is never binding in the simulations.

Risk-free rate	r	4%
Discount factor	β	0.92
Income autocorrelation coefficient	ρ	0.66
Minimum bond price	$\underline{q}$	0.45
Standard deviation of innovations	σ_ϵ	3.4%
Mean log income	μ	$(\text{-}1/2)\sigma_\epsilon^2$
Government consumption	g	0.12
Recovery rate	α	63%
Debt duration	δ	0.286
Probability of exiting high risk premium	π_{HL}	0.8
Cost of defaulting	λ_0	0.5305
Cost of defaulting	λ_1	4.64
Borrower's risk aversion	γ	2.19
Probability of entering high risk premium	π_{LH0}	0.38
Probability of entering high risk premium	π_{LH1}	38
Risk-premium shock	p_H	3.8

Table 1: Parameter Values.

We use data from Mexico, a common reference for quantitative studies of sovereign default, for choosing the parameters that govern the endowment process, the level and duration of debt, and the mean spread (Mexico displays the same properties that are observed in other emerging economies and in advanced economies facing default risk; see Aguiar and Gopinath, 2007; Alvarez et al., 2013; Neumeyer and Perri, 2005; and Uribe and Yue, 2006). Unless specified otherwise, we use data from 1993 to 2014. The parameter values that govern the endowment process are chosen to mimic the behavior of logged and linearly detrended GDP in Mexico during that period.

The level of public expenditure g is set to 12 percent of average income to match the average level of public consumption to GDP in Mexico. We set $\delta = 0.2845$. With this value and the targeted level of sovereign spread, sovereign debt has an average duration of 3 years in the simulations, which is roughly the average duration of public debt in Mexico.[6]

Following Bianchi et al. (2018), we assume there are three high risk-premium episodes every twenty years and that each episode lasts on average for 1.25 years. We set the probability of exiting a high-risk-premium period to $\pi_{HL} = 0.8$ and we calibrate the parameters of the probability of entering a high-risk-premium period to match the frequency of such periods and the lower level of income during such periods. Looking at the EMBI spread for all available countries not in default (according to Fitch) since 1994, one can identify three episodes of high average sovereign spreads (when spreads where higher than the sample mean plus one standard deviation) in the last twenty years: 1994-1995 (Tequila crisis), 1998 (default in Russia), and 2008 (Global Financial Crises). The average EMBI spread was more than 3 percentage points higher in those episodes than in normal periods. In Mexico, the average spread was 2 percent higher during those episodes. Our calibration approach is consistent with proposals of using the EMBI as the trigger for reprofiling in cocos (IMF, 2017a). As Bianchi et al. (2018), we assume $p_L = 0$ (lenders are risk-neutral in good times) and calibrate p_H targeting the average spread increase triggered by high risk premium.

We calibrate the cost of defaulting (two parameters), the borrower's risk aversion, the prob-

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[6]We use data from the central bank of Mexico for debt duration, and 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.

ability of entering a high-risk-premium period (two parameters), and the risk premium (λ_0, λ_1, γ, π_{LH0}, π_{LH1}, and p_H, respectively) targeting six moments: A mean spread of 2.4 percent, a mean public debt to GDP ratio of 43.5 percent, a volatility of consumption equal to the volatility of income, three high-risk-premium episodes every twenty years, an average income 4 percent lower during these episodes (Calvo et al., 2006), and spread increase during high-risk-premium episodes of 2 percentage points. The targets for the levels of debt and spread are from Mexico. We target a volatility of consumption equal to the volatility of income following Bianchi et al. (2018).[7] The target for the increase in the spread during episodes with high risk premium is the average increase in Mexico's EMBI spreads during the three episodes described in the previous paragraph.

The recursive problem is solved using value function iteration. We solve the optimal borrowing 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 functions for equilibrium bond prices q and q_C are approximated using linear interpolation over y and cubic spline interpolation over debt levels. We use 20 grid points for debt levels, and 25 grid points for income realizations. Expectations are calculated using 50 quadrature points for the income shocks. As Hatchondo et al. (2010), we solve for the equilibrium of the finite-horizon version of our economy. That is, 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 that the maximum deviation between the value and bond price functions in the first and second period is no larger than 10^{-6}.

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[7]As discussed by Bianchi et al. (2018), the domestic risk aversion is a key parameter determining the government's willingness to tolerate liquidity shocks. In general, in equilibrium default models, governments may be too eager to lower consumption in response to adverse shocks (Aguiar et al., 2016). This is in part because quantitative studies of sovereign default that do not make domestic risk aversion part of the calibration and present a volatility of consumption significantly higher than the volatility of income. This is consistent with the data for total consumption in emerging markets. However, the model features only non-durable consumption, and non-durable consumption is less volatile than GDP in emerging markets. Alvarez et al. (2013) show that the ratio of the standard deviations of consumption and income is 0.9 both on average for emerging markets and for Mexico. Targeting a volatility of consumption equal to the volatility of income brings us closer to the data for non-durable consumption without presenting a major departure from previous studies (note also that the model does not feature durable consumption, which is more volatile than GDP). The value of the risk aversion parameter that results from the calibration ($\gamma = 2.2$) is well within the range of values used for macro models.

Table 2 reports moments in the data and in the simulations of the benchmark economy with non-contingent debt. Simulations match the moments targeted in the calibration well.

4 The effects of cocos

We evaluate the effects of cocos by comparing simulation results in the benchmark economy without cocos with the ones obtained when we assume the government can issue both non-contingent bonds and cocos. We assume suspended payments earn the risk-free rate ($r_C = r$) and thus the nominal haircut from triggering the contingency clause in cocos is equal to zero.

Table 2 shows that, as anticipated by critics of cocos, cocos increase the default frequency, which is reflected in higher spreads. This occurs because the debt level increases with cocos. The government borrows more with cocos because it does not have to worry about the rollover risk implied by risk-premium shocks.[8]

Table 2 also shows that as anticipated by critics of cocos, cocos exacerbate the spread increase triggered by the risk-premium shock. This occurs even though the reprofiling of cocos payments eliminates defaults triggered by risk-premium shocks, and because (i) lenders dislike the postponement of payments precisely when the risk premium is high and they value payments the most and (ii) the suspension of payments triggered by financing shocks leads to an increase of debt levels while the government faces these shocks.

Figure 1 shows that introducing cocos increases welfare.[9] The initial consumption increase

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[8]When we simulate the cocos economy without allowing the government to buy back debt, we find almost identical results, indicating that buybacks (for example, motivated by changes in the lenders' valuation of sovereign debt) do not play a significant role in the simulations. When we simulate the economy with only cocos (instead of both cocos and non-contingent debt), we find similar results but a slightly higher debt level (54.6), spread (2.9), and default probability (7.2). This may be due to the longer duration of cocos worsening the government's time inconsistency problem (Hatchondo et al., 2020a). These relatively mild effects of the duration of cocos is consistent with those discussed in footnote 11.

[9]We measure welfare gains from introducing cocos as the constant proportional change in consumption that would leave a consumer indifferent between living in the economy without cocos and living in the economy with cocos. These welfare gains are given by

$$\left[\frac{\hat{V}^{\text{Non-contingent}}(b, y, p, l)}{\hat{V}^{\text{Cocos}}(b, 0, y, p, l)} \right]^{\left(\frac{1}{1-\gamma} \right)} - 1,$$

where the superindex "Non-contingent" refers to the value function in the benchmark economy and the superindex

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	Data	Benchmark	With cocos
Mean debt/y (%)	43.0	43.1	3.9
Mean cocos debt/y (%)	*n.a.*	*n.a.*	49.0
Mean r_s (%)	2.4	2.4	2.4
Mean cocos r_s (%)	*n.a.*	*n.a.*	2.8
Defaults per 100 years	*n.a.*	6.2	6.8
Duration	3.0	3.0	3.0
Duration cocos	*n.a.*	*n.a.*	3.6
$\sigma(c)/\sigma(y)$	1.0	0.99	0.97
$\sigma(r_s)$	0.9	1.4	1.6
$\sigma(r_s)$ cocos	*n.a.*	*n.a.*	1.8
$\rho(c,y)$	0.80	0.97	0.90
Probability high-risk-premium starts (%)	15.0	15.0	15.0
Lower income during high-risk-premium (%)	4.0	4.1	4.4
$\Delta\, r_s$ with high-risk-premium shock	2.0	2.1	3.1
$\Delta\, r_s$ cocos with high-risk-premium shock	*n.a.*	*n.a.*	2.7
Fraction of defaults triggered by liquidity (%)		3.2	0.0

Table 2: Effects of introducing cocos. The standard deviation of x is denoted by $\sigma(x)$. Moments are computed using detrended series. Trends are computed using the Hodrick-Prescott filter with a smoothing parameter of 100. 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. Simulation samples start at least five years after a default. Default episodes are excluded to improve comparability with the data. Consumption and income are expressed in logs. Default frequencies and the probability that a high-risk-premium episode starts are computed using all simulation periods. For cocos, the yield (and spread), the debt duration, and the debt stock are computed using expected payments and thus incorporate uncertainty about the time of payment.
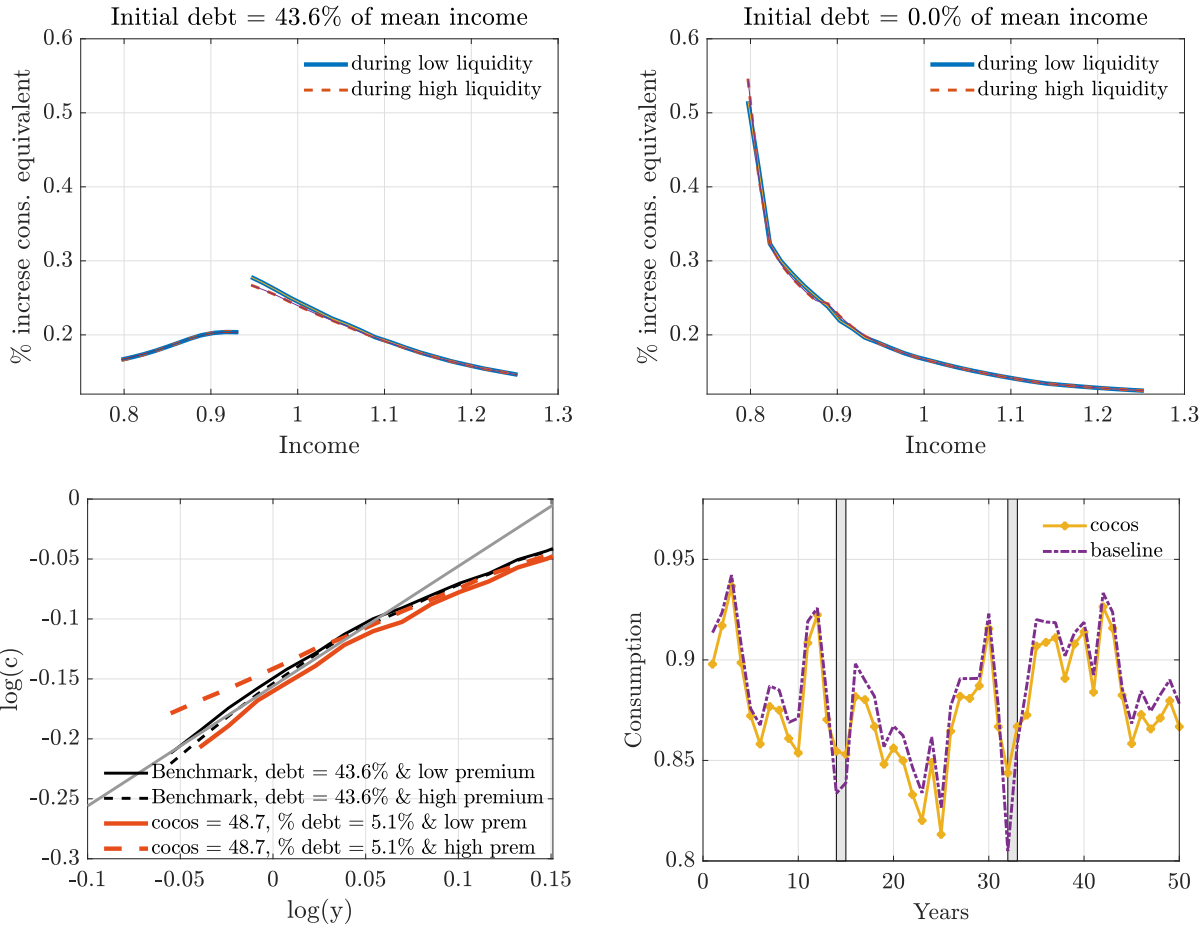
Figure 1: Welfare gains from introducing cocos.

triggered by the government's willingness to sustain higher levels of indebtedness with cocos accounts for the bulk of these welfare gains. In addition, as expected by proponents of cocos and illustrated in Table 2 and the bottom panels of Figure 1, cocos improve consumption smoothing. As illustrated by the bottom-left panel, while a higher lenders' risk aversion lowers consumption in the benchmark economy, it increases consumption in the economy with cocos. But in the standard default model the effect of lowering consumption volatility on welfare are small. Welfare gains from tilting consumption and improving consumption smoothing overcome the welfare losses implied by the higher default frequency with cocos.

"Cocos" refers to the economy with cocos. Thus, a positive welfare gain means that agents prefer the economy with cocos.
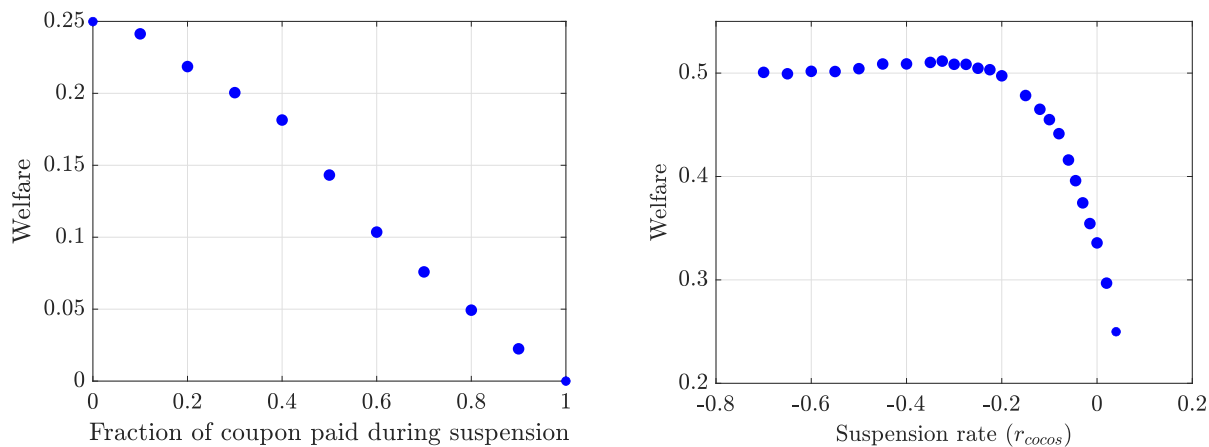
Figure 2: Optimal cocos debt relief.

5 How much debt relief?

Following existing proposals, the previous section assumes that cocos suspend all debt payments and do not imply a nominal haircut on the level of debt ($r_C = r$). But is this level of debt relief implied by cocos optimal? The left panel of Figure 2 illustrates how the sovereign does not want less debt relief: Welfare gains would be lower if cocos trigger less debt relief by suspending only a fraction of debt payments.[10]

The right panel of Figure 2 shows that the government would benefit from cocos that provide additional debt relief: The optimal rate of growth of suspended cocos payments (r_C) is negative, indicating that it is optimal for cocos to trigger haircuts after adverse shocks (recall that for our benchmark cocos, $r_C = r$). Recall that without haircuts, cocos result in a higher default probability, reflected in higher spreads, and in a larger spread increase triggered by risk-premium shocks. Table 3 shows that, in contrast, with haircuts, cocos result in a significantly lower default probability, reflected in lower spreads, and in a lower spread increase triggered by risk-premium shocks. Haircuts also improve consumption smoothing implying a lower consumption volatility.

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[10]Let θ denote the fraction of coupons paid during the cocos payment suspension. The next-period stock of cocos is given by

$$b'_C = [1 - \mathcal{I}(p)]\, b_C(1 - \delta_C) + \mathcal{I}(p)b_C[\theta(1 - \delta) + (1 - \theta)e^{r_C}] + i_C.$$

Note that $\theta = 1$ makes the debt non-contingent and $\theta = 0$ corresponds to the case in which all cocos payments are suspended.

In response to the risk-premium shock, cocos that trigger only a suspension of payments increase the level of debt (because of the automatic rollover of suspended payments) thus increasing the default probability and the spread. This impairs the government's ability to borrow for consumption smoothing. In contrast, with haircuts, cocos lower the level of debt, the default probability, and the spread, improving the government's ability to borrow for consumption smoothing.

The right panel of Figure 2 shows that welfare gains from increasing haircuts level off after sufficient debt relief is provided. This occurs because, as illustrated in Table 3 , if cocos provide too much debt relief (haircuts are too high), the government can always compensate by issuing fewer cocos and more non-contingent bonds.[11]

6   Conclusions

We study a model of equilibrium sovereign default in which the government issues cocos that stipulate a suspension of debt payments in periods of low global liquidity. We show that as argued by proponents of sovereign cocos, cocos reduce the frequency of sovereign defaults triggered by liquidity shocks, and increase consumption in periods of low liquidity. However, cocos increase the overall default frequency because they increase indebtedness. We also find that even a full suspension of debt payments does not provide sufficient debt relief: Allowing for cocos to trigger haircuts is welfare enhancing, and cocos with haircuts reduce the default frequency. While we present results for shocks to global liquidity as the trigger of debt relief in cocos, results are similar when we model other shocks as triggers, including shocks to the government's financing needs (see Appendix A).

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[11]Note however that in the model, the government's ability to compensate for excessive debt relief in cocos is not perfect. Cocos and non-contingent bonds have different durations and committing to higher haircuts implies commitment to a shorter expected duration. Longer durations imply stronger ex-post incentives to dilute the value of bonds held by lenders (Hatchondo et al., 2020a). Nevertheless, the right panel of Figure 2 indicates that the effective duration of cocos does not have a significant effect on welfare. To assure our findings are not significantly contaminated by the assumed duration of cocos, we also run our experiments with different durations and find equivalent results.

	Benchmark	$r_C = r$	$r_C = -0.25$	$r_C = -0.45$
Mean debt/y (%)	43.09	3.90	10.36	15.24
Mean cocos debt/y (%)	n.a.	49.03	45.28	39.95
Mean r_s (%)	2.40	2.42	1.69	1.57
Mean cocos r_s (%)	n.a.	2.76	1.76	1.48
Defaults per 100 years	6.20	6.79	4.56	4.11
$\sigma(c)/\sigma(y)$	0.99	0.97	0.92	0.93
$\Delta\, r_s$ with shock	2.10	3.09	1.98	1.71
$\Delta\, r_s$ cocos with shock	n.a.	2.82	1.92	1.65

Table 3: Cocos paying different interest rates r_C during suspensions.

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Online Appendix

A An alternative liquidity shock

To illustrate the robustness of our findings to the type of liquidity shock we consider, we next study shocks that increase the government's gross financing needs (for instance, because of natural disasters) and we shut off the risk-premium shock. Formally, we assume that government expenditures g may take a low or a high value: $g_t \in \{g_l, g_h\}$ and we set $p_H = 0$. The shock g_t follows a Markov process with the same structure of the risk-premium shock. We set the high level g_h to 22 percent to capture a 10 percent increase in public expendtirues due to the shock, which is consistent with the size of contingent liability realizations reported by Bova et al. (2016). The rest of the parameters in the model keep the same values of the calibration discussed in Section 3 and are presented in Table 4.

Table 5 reports moments in the simulations of the alternative liquidity shock economy with non-contingent debt and with cocos. Figure 3 shows the optimal debt relief results under this alternative liquidity shock. Overall, we obtain the same qualitative results as with the risk-premium shock. Cocos reduce the frequency of sovereign defaults triggered by liquidity shocks, and increase consumption in periods of low liquidity. However, cocos increase the overall default frequency because they increase indebtedness. A full suspension of debt payments does not provide sufficient debt relief: Allowing for cocos to trigger haircuts is welfare enhancing but these level off after sufficient debt relief is provided.

Risk-free rate	r	4%
Discount factor	β	0.92
Income autocorrelation coefficient	ρ	0.66
Minimum bond price	$\underline{q}$	0.45
Standard deviation of innovations	σ_ϵ	3.4%
Mean log income	μ	$(-1/2)\sigma_\epsilon^2$
Government consumption	g_l	0.12
Recovery rate	α	63%
Debt duration	δ	0.286
Probability of exiting high risk premium	π_{HL}	0.8
Cost of defaulting	λ_0	0.5305
Cost of defaulting	λ_1	4.64
Borrower's risk aversion	γ	2.19
Probability of entering g_h	π_{LH0}	0.38
Probability of entering g_h	π_{LH1}	38
Government consumption	g_h	0.22

Table 4: Parameter Values under Alternative Liquidity Shock.

	Benchmark	With cocos
Mean debt/y (%)	37.1	3.0
Mean cocos debt/y (%)	n.a.	45.1
Mean r_s (%)	2.0	2.1
Mean cocos r_s (%)	n.a.	2.7
Defaults per 100 years	6.4	7.7
Duration	3.1	3.1
Duration cocos	n.a.	3.6
$\sigma(c)/\sigma(y)$	1.2	1.1
$\sigma(r_s)$	1.4	1.7
$\sigma(r_s)$ cocos	n.a.	1.8
$\rho(c, y)$	0.92	0.90
Probability g_h episode starts (%)	15.0	15.0
Lower income during g_h (%)	4.3	4.7
$\Delta\, r_s$ with g_h shock	2.7	3.9
$\Delta\, r_s$ cocos with g_h shock	n.a.	3.5
Fraction of defaults triggered by liquidity (%)	1.1	0.0

Table 5: Effects of introducing cocos for an economy with the alternative liquidity shock. The standard deviation of x is denoted by $\sigma(x)$. Moments are computed using detrended series. Trends are computed using the Hodrick-Prescott filter with a smoothing parameter of 100. 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. Simulation samples start at least five years after a default. Default episodes are excluded to improve comparability with the data. Consumption and income are expressed in logs. Default frequencies and the probability that a high-public-expenditure episode starts are computed using all simulation periods. For cocos, the yield (and spread), the debt duration, and the debt stock are computed using expected payments and thus incorporate uncertainty about the time of payment.
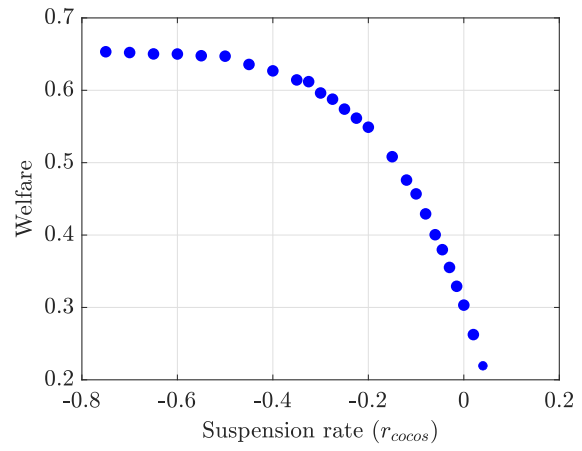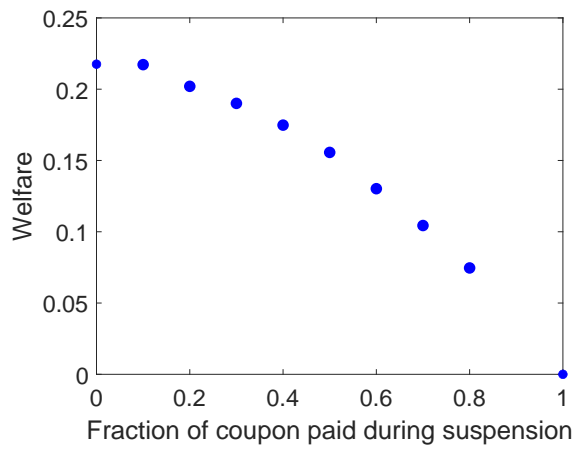
Figure 3: Optimal cocos debt relief - Alternative Liquidity Shock.