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SOVEREIGN COCOS AND DEBT FORGIVENESS

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Abstract

We study a sovereign default model in which the government issues CoCos (contingent convertible bonds) that stipulate a suspension of debt payments upon a sizeable increase of the global risk premium (and thus, of the government's borrowing cost). We find that CoCos allow the government to smooth out the effects of risk-premium shocks on consumption, but they increase the default frequency. By suspending debt payments, CoCos imply higher debt levels and thus higher default probabilities after adverse shocks. We also study CoCos that in addition to the payment suspension, stipulate debt forgiveness after adverse shocks. In contrast with no-forgiveness CoCos, debt-forgiveness CoCos reduce debt levels after adverse shocks, thereby reducing default probabilities. Debt-forgiveness CoCos also yield larger welfare gains.

Keywords: Sovereign default, CoCos, debt relief, reprofiling, debt forgiveness.

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1 Introduction

This paper presents a quantitative analysis of sovereign "CoCos" (contingent convertible bonds) with a trigger clause that postpones debt payments for governments facing sizeable adverse shocks to its borrowing opportunities. On the one hand, proponents of CoCos argue that these bonds would provide needed debt relief to governments facing adverse shocks, avoiding government defaults on its debt obligations and the associated costs (Consiglio and Zenios, 2018; Ross and Ulukan, 2020). On the other hand, critics of CoCos underscore that if the triggering of maturity-extending clauses becomes more likely, creditors would scramble out of the market, which could ultimately increase the likelihood of debt crises and hurt the sovereign (FT, 2013, 2014). Would introducing CoCos reduce or increase the frequency of sovereign defaults and the sovereign spreads paid by the government? Would they benefit the government? Would CoCos provide optimal debt relief or should the postponement of payments mandated by CoCos be accompanied by debt forgiveness? This paper sheds light on these and other questions.

We measure the effects of introducing CoCos using the quantitative sovereign default framework à la Eaton and Gersovitz (1981) that was first used for quantitative analysis by Aguiar and Gopinath (2006) and Arellano (2008). We augment the baseline model with a risk premium shock (a shock to external lenders' risk aversion), a global shock commonly mentioned as a possible trigger of reprofiling in policy discussion (IMF, 2017a).[1] In the baseline model, the government issues only non-contingent bonds. In the extended model, the government can also issue CoCos for which payments are postponed 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 risk-premium shocks, and allow the government to smooth the effect of these shocks on consumption. However, as argued by critics of CoCos, CoCos augment the spread volatility and the increase in spreads triggered by adverse shocks. This occurs because

[1] Section 7.3 presents equivalent results when we model domestic shocks to the government's financing needs (e.g., natural disaster shocks) as the trigger of CoCos debt relief.

the postponement of payments triggered by risk-premium shocks leads to an increase in debt levels while the government faces these shocks (this is similar to the debt increase triggered by partial defaults documented by Arellano et al., 2022), increasing the default probability after the postponement of payments ends. Furthermore, due to higher debt levels, the overall default frequency is also higher with CoCos.

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 postponement of debt payments is accompanied by debt forgiveness. Practitioners discount the possibility of complementing the postponement of debt payments in sovereign CoCos with debt forgiveness because they anticipate debt forgiveness would increase the interest rate governments pay when issuing debt (Ross and Ulukan, 2020). We find that with debt-forgiveness CoCos, lenders indeed ask for a higher interest rate as a compensation for lower expected payments. However, the government chooses to issue a portfolio of non-contingent bonds and debt-forgiveness CoCos such that it lowers not only the average spread, but also the spread increase triggered by the risk-premium shock and the overall spread volatility. This occurs because timely debt forgiveness triggered by CoCos lowers default risk, in contrast with what we find in the simulations of the model with no-forgiveness CoCos.

Related literature Consiglio and Zenios (2018) present a thorough discussion of implementation issues for sovereign CoCos. They define a sovereign CoCo as "A sovereign debt instrument with a built-in trigger to allow payment standstill for a grace period when an indicator breaches a threshold." This definition applies for the CoCos in our model. The European debt crisis revived discussions about policies to mitigate the likelihood and the costs of sovereign debt crises. These issues continue to receive attention as in response to COVID-19, governments implemented large fiscal stimulus programs that pushed public debt to historically high levels. The reprofiling of sovereign debt—extending the maturity of debt instruments or imposing a debt service standstill when the government faces adverse risk-premium shocks—plays a central role in policy discussions.[2] Several proposals entail governments issuing CoCos or "extendible" bonds with a

[2]To prevent crises, Buiter and Sibert (1999) propose a Universal Debt Rollover Option entitling (both private

trigger clause that suspends debt payments after adverse shocks (Barkbu et al., 2012; Brooke et al., 2011; Buiter and Sibert, 1999; IMF, 2017a,b; Ross and Ulukan, 2020; Weber et al., 2011). Debt moratoria, have also been discussed for corporate loans (Önder et al., 2023) and mortgages (Guler et al., 2024a; Guler et al., 2024b).

How should the postponement of CoCos payments be triggered? For the practical applicability of CoCos, different proposals emphasize using as the trigger for payment postponement variables that are closely tied to the government's repayment capacity but are not easily manipulable by the government. For example, Consiglio and Zenios (2018) and Consiglio et al. (2018) recommend sovereign CoCos that suspend debt payment when the sovereign CDS spread is high (see also Barkbu et al., 2012, IMF, 2017a, and IMF, 2017b). While governments could manipulate the CDS spread to trigger CoCos debt relief, doing so would be too costly, as it would not only deteriorate the government's access to debt markets but also credit to the private sector (Arellano et al., 2020). Consiglio and Zenios (2018) also argue that to better capture global factors (outside the control of the government), one could also use the average sovereign spread across countries as the trigger for payment postponement. We use exceptional increases in the average sovereign spread across countries to calibrate the global shock that triggers payment postponement in our model. To mitigate concerns about the use of market indicators for triggering CoCos, Consiglio and Zenios (2018) argue that the official sector (e.g., the European Stability Mechanism) could mediate in this triggering.[3] Some proposals also discuss the sovereign receiving liquidity (and not solvency) assistance from the official sector as a trigger for the reprofiling of private debt (Brooke et al., 2011; IMF, 2014; Weber et al., 2011). Such reprofiling could be facilitated if the sovereign had CoCos (Consiglio and Zenios, 2018). Barbados and Grenada used natural disasters (that diminish the government's repayment capacity and are outside the control of the government) as the trigger for the reprofiling of sovereign bond payments (Ho and Crane, 2020). We show that our findings are robust to modeling a shock that triggers CoCos relief that mimics the cost of natural disasters.

and sovereign) borrowers to extend performing debt for a specified period at a penalty rate. In response to COVID-19, the G20 agreed to a debt service standstill on bilateral loans to low-income countries.

[3]Bank CoCos often allow for debt writedowns triggered either by the regulator or because bank capital falls below a threshold.

Benefits from CoCos would arise in part because, in the face of adverse shocks, CoCos could provide debt relief without triggering a credit event and the associated costs (Consiglio and Zenios, 2018; Ho and Crane, 2020; Ross and Ulukan, 2020). A crucial difference between the debt relief obtained through CoCos and the debt relief obtained through a sovereign default is that by introducing the terms of the debt relief in the contract, CoCos (in contrast with defaults) would not imply a violation of debt contracts and the associated costs (the lengthy negotiations, litigation, difficulties in market access, and reputational costs that often follow outright defaults). Precisely, the possibility of lowering the government's debt obligations in times of need without a violation of debt contracts (and the implied costs) is the motivation for introducing CoCos.

Sovereign CoCos may also provide a superior alternative over the perceived costs of receiving liquidity assistance from international organizations, which is apparent from sovereigns' precautionary motive for asset accumulation (Bianchi et al., 2018). 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)." CoCos could automatize such extension of maturities.

Sovereign CoCos are only part of the set of state-contingent debt instruments (SCDI) for sovereigns discussed in both academic and policy circles (IMF, 2017a). Contingent debt instruments differ 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 postponement or payment reduction). CoCos postpone payments but do not reduce the stock of debt. Section 5 introduces debt-forgiveness CoCos that reduce the stock of debt. Section 6 introduces income-linked bonds that reduce indebtedness by reducing coupon payments.

Hatchondo and Martinez (2012), Hatchondo et al. (2016), and Önder (2023) 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.[4] In contrast with these findings (for which

[4] 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.

non-contingent debt is replaced by contingent debt), Section 6 shows that introducing income-linked bonds (in addition to non-contingent debt) results in higher debt levels that imply a higher default probability. Thus, in our simulations, only the introduction of debt-forgiveness CoCos (that lower the stock of debt after adverse shocks, and not only coupon payments as income-link bonds) imply lower default probabilities.

Borensztein et al. (2017), Mallucci (2022), 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 (2022) finds 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.

In the light of theoretical results, the scarce use of contingent bonds is somewhat puzzling. Roch and Roldán (2023) argue that this scarce use may be due to uncertainty premia and the poor design of state contingent debt. While contingent bonds have not been widely used, there have been some experiences, mostly as part of debt restructurings, including the recent experiences of Barbados and Grenada using natural disasters as the trigger for the reprofiling of sovereign bond payments (Ho and Crane, 2020).

The gains from introducing debt-forgiveness CoCos found in our paper may appear to contradict the welfare losses triggered by larger post-default haircuts found by Arellano et al. (2022). However, there is a substantial difference between the two exercises. Recall the government cannot commit to an ex-ante optimal default policy and thus ends up defaulting too much from an ex-ante perspective. The larger post-default haircuts studied by Arellano et al. (2022) exacerbate this problem. In contrast, we study debt forgiveness that is automatically triggered by risk-premium shocks and thus is not subject to the default time inconsistency problem.

Hatchondo et al. (2020b) find that unanticipated debt forgiveness is part of the optimal one-time unanticipated debt relief in response to a one-time large unanticipated shock like COVID-19. In their setup, debt forgiveness is 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 risk-premium shocks, and we find the optimal design of CoCos includes anticipated debt forgiveness, even though debt forgiveness is fully priced by lenders.

Aguiar et al. (2019), Dvorkin et al. (2020) and Mihalache (2020) analyze the trade offs between using extensions of maturity or debt forgiveness in sovereign debt restructurings. Dvorkin et al. (2020) discuss a regulatory cost of debt forgiveness that helps 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 debt forgiveness 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.

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 on top of payment postponements, adverse shocks trigger CoCos debt forgiveness. Section 6 discusses income-linked bonds. Section 7 shows the robustness of our findings. Section 8 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. Within each period, the timing of events is as follows. First, the endowment and risk-premium shocks are realized. If the government is not in default, it chooses whether to default 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 government The government cannot commit to future (borrowing and default) decisions. We focus on the Markov Perfect Equilibrium. 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. Following Bianchi et al. (2018), we assume a fixed level of government expenditures $g > 0$.

Lenders The price of non-contingent sovereign bonds satisfies a no-arbitrage condition with stochastic discount factor

$$M(\varepsilon', p) = exp(-r - p\varepsilon' - 0.5p^2\sigma_\varepsilon^2), \tag{1}$$

where r denotes the risk-free rate at which lenders can borrow or lend and p represents bondholders' risk aversion (Bianchi et al., 2018). Since the repayment decision is positively correlated with income, the risk-premium compensation increases with p. The price of CoCos satisfies a no-arbitrage condition with stochastic discount factor

$$M^C(\varepsilon', p) = exp(-(r + \ell^C) - p\varepsilon' - 0.5p^2\sigma_\varepsilon^2), \tag{2}$$

where ℓ^C denotes the liquidity premium demanded to hold a CoCo bond. This captures in a simple and tractable way a usual concern against the introduction of new debt instruments: Investors may ask an extra compensation to buy them if they are viewed as less liquid than standard bonds.

The bondholders' risk-premium shock, $p \in \{p_L, p_H\}$ with $p_L < p_H$, 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: $\pi_{LH}(y) = Min\left\{\pi_0 e^{-\pi_1 \log(y) - 0.5\pi_1^2\sigma_\varepsilon^2}, 1\right\}$.

Bonds A non-contingent bond issued in period t promises to pay $\delta(1-\delta)^{j-1}$ units of the tradable good in period $t+j$, for all $j \geq 1$ (Hatchondo and Martinez, 2009). Hence, non-contingent debt dynamics can be represented as $b_{t+1} = (1-\delta)b_t + i_t$, where δb_t are the payments due in period t, and i_t is the mass of non-contingent bonds issued in period t.

CoCos promise an infinite stream of coupon payments that decrease at the constant rate δ_C. In periods with high risk-premium ($p_t = p_H$), all CoCos payments are postponed until global markets improve ($p_t = p_L$). Creditors earn the rate r_C (which is part of the CoCos contract) on postponed payments. This is, debt grows at the rate r_C when payments are postponed.

If the government is not in default and CoCos payments are suspended, consumption is given by

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

where $s \equiv (y, p)$ denotes the vector of exogenous states, and q and q_C denote the price of non-contingent bonds and CoCos, respectively. If CoCos payments are not suspended, consumption is given by

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

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

Defaults As is standard in the literature, when the government defaults, it does so on current and future debt obligations. A defaulting government cannot borrow and suffers a one-time utility loss $U^D(y)$ (Bianchi et al., 2018). The period after 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 (Hatchondo et al. (2016)).[5]

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 defaults and is not binding in the simulations.

2.1 Recursive Formulation

Let V denote the value function of a government that is not currently in default. The function V satisfies the following functional equation:

$$V(b, b_C, s) = \max \left\{ V^R(b, b_C, s), V^D(b, b_C, s) \right\}, \tag{3}$$

where the government's value of repaying is given by

$$V^R(b, b_C, s) = \max_{i \geq 0, i_C \geq 0, c \geq 0} \left\{ u\left(c\right) + \beta \mathbb{E}_{(s')|(s)} V(b', b'_C, s') \right\}, \tag{4}$$

subject to

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

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

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

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

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

and $\mathcal{I}$ is an indicator function that is equal to 1 in states where the payment suspension clause is triggered, namely

$$\mathcal{I}(p) = \begin{cases} 1 & \text{if } p = p_H, \\ 0 & \text{otherwise.} \end{cases}$$

[5] 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 (Arellano, 2008; Bianchi et al., 2018). Section 7 shows that our results are robust to assuming a longer duration of default episodes.

Note that we assume that the suspension of CoCos payments does not impair the government's ability to borrow. This is the case because, in contrast with a default (that violates debt contracts and impairs the government's ability to borrow), the postponement of CoCos payments is not a violation of the CoCos contract.

The value of defaulting is given by:

$$V^D(b, b_C, s) = u\left(y - g\right) - U^D(y) + \beta \mathbb{E}_{s'|s}\left[V(\alpha b, \alpha b_C, s')\right]. \tag{5}$$

The price of non-contingent bonds is given by

$$q(b', b'_C, s) = \qquad \mathbb{E}_{s'|s}\big[M(\varepsilon', p)[\underbrace{d'\alpha q\left(\alpha b', \alpha b'_C, s'\right)}_{\substack{\text{There is a default and}\\ \text{creditors receive } \alpha \text{ bonds}\\ \text{per bond in default.}}} + \underbrace{(1-d')[\delta + (1-\delta) q\left(b'', b''_C, s'\right)]}_{\substack{\text{The government repays, creditors receive}\\ \text{coupon } \delta \text{ and are entitled to remaining}\\ \text{coupon stream, worth } (1-\delta)q\left(b'', b''_C, s'\right).}}\big], \tag{6}$$

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.

The price of a CoCo is given by

$$\begin{aligned} q_C(b', b'_C, s) = \mathbb{E}_{s'|s}\Bigg[& M^C(\varepsilon', p)\Big[d'\alpha q_C\left(\alpha b', \alpha b'_C, s'\right) \\ & + (1-d')\big[\left[1 - \mathcal{I}(p')\right]\left[\delta_C + (1-\delta_C) q_C\left(b'', b''_C, s'\right)\right] \\ & + \mathcal{I}(p') e^{r_C} q_C\left(b'', b''_C, s'\right)\big]\Big]\Bigg], \end{aligned} \tag{7}$$

where the first line describes what a creditor expects to recover per bond in the event of a default, the second line describes the coupon payment and ex-coupon value of a bond after the government repays and there is no payment suspension, and the third line describes the value of a bond in a period with payment suspension.

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 (3), (4), and (5).

ii. given policy rules $\left\{\hat{d}, \hat{b}, \hat{b}_C\right\}$, the bond price functions q and q_C satisfy conditions (6) and (7), 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.,

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

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

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 not binding in the simulations. This is, $\underline{q} = 0.45$ is one of the many possible values of $\underline{q}$ that avoids a second interior local maximum with a 100 percent default probability in the government's maximization problem (Hatchondo et al., 2014). The limit $\underline{q} = 0.45$ is not binding as the government chooses an interior maximum with a positive repayment probability.

Risk-free rate	r	4%
Liquidity premium for holding CoCos	ℓ^C	0
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	0.12
Recovery rate	α	63%
Debt duration	δ	0.2845
Probability of exiting high risk premium	π_{HL}	0.8
Cost of defaulting	λ_0	0.5305
Cost of defaulting	λ_1	4.64
Government's risk aversion	γ	2.19
Probability of entering high risk premium	π_0	0.38
Probability of entering high risk premium	π_1	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; 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 Macaulay duration of 3 years in the simulations, which is roughly the average duration of public debt in Mexico (as reported by its Central Bank).

We assume that there are three high risk-premium episodes every twenty years and that each episode lasts on average for 1.25 years (Bianchi et al., 2018). 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.

We assume $p_L = 0$ (lenders are risk-neutral in good times) and calibrate p_H targeting an average spread increase triggered by a high risk premium of 2 percent (Bianchi et al., 2018). 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 were 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 percentage points higher during those episodes. Our calibration approach is consistent with proposals of using the EMBI as the trigger for reprofiling in CoCos (IMF, 2017a).

We calibrate the cost of defaulting (two parameters), the borrower's risk aversion, the probability of entering a high-risk-premium period (two parameters), and the risk premium (λ_0, λ_1, γ, π_0, π_1, and p_H, respectively) targeting six moments: A mean spread of 2.4 percent (Mexico), a mean public debt to GDP ratio of 43.5 percent (Mexico), a volatility of consumption equal to the volatility of income (Bianchi et al., 2018), three high-risk-premium episodes every twenty years, an average income 4 percent lower during these episodes (Calvo et al., 2006), and the spread increase during high-risk-premium episodes of 2 percentage points mentioned above.

3.1 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 enough periods to make the maximum deviation between the value and bond price functions in the first and second period is no larger than 10^{-6} (Hatchondo et al., 2010). We use 40 grid points for non-contingent debt and CoCos, and 30 grid points for income realizations. Expectations are calculated using 100 quadrature points for the income shocks. We solve the optimal borrowing in each state by searching over the grids for non-contingent debt and CoCos. Then, we use the best portfolio on those grids as the initial guess in a nonlinear optimization routine. The value

	(1) Data	(2) Benchmark	(3) CoCos	(4) CoCos Debt $\leq 43\%$	(5) CoCos $r_C = -0.325$	(6) Income linked
Targeted moments (in the benchmark)						
Mean debt/y (%)	43.0	43.1	3.9	6.2	12.5	40.1
Mean r_s (%)	2.4	2.4	2.4	1.7	1.6	2.1
Prob. high risk-premium shock (%)	15.0	15.0	15.0	15.0	15.0	15.0
Lower y during high risk-premium (%)	4.0	4.1	4.4	4.5	4.9	4.5
$\sigma(c)/\sigma(y)$	1.00	0.99	0.97	1.20	0.93	0.70
Δ r_s with high-risk-premium shock	2.0	2.1	3.1	2.2	1.8	1.8
Duration	3.0	3.0	3.0	3.1	3.1	3.1
Other moments						
Mean contingent debt/y (%)	*n.a.*	*n.a.*	49.0	36.5	33.3	36.0
Mean contingent r_s (%)	*n.a.*	*n.a.*	2.8	2.0	1.6	0.9
Defaults per 100 years	*n.a.*	6.2	6.8	4.7	4.3	8.3
Duration contingent debt	*n.a.*	*n.a.*	3.6	3.9	3.1	3.3
$\sigma(r_s)$	0.9	1.4	1.6	1.1	1.2	1.1
$\sigma(r_s)$ contingent debt	*n.a.*	*n.a.*	1.8	1.2	1.1	1.4
$\rho(c, y)$	0.8	1.0	0.9	1.0	0.8	-0.1
Δ contingent r_s with high risk-premium	*n.a.*	*n.a.*	2.7	2.1	1.8	2.0
% of defaults triggered by risk-premium shock	*n.a.*	3.2	0.0	1.5	0.0	3.4

Table 2: Effects of introducing state-contingent debt instruments. 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. The spread yield, debt duration, and debt stock are computed assuming no defaults. The debt stock consists of the present discounted value of promised debt payments (which are uncertain in the case of CoCos and income-linked bonds), discounted at the risk-free interest rate. The debt measure of CoCos with debt forgiveness ($r_C = -0.325$) takes into account the reduced debt payments that follow an episode of payments suspension.

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

4 The effects of CoCos

We evaluate the effects of introducing 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 first assume there is no liquidity premium for CoCos and $\ell^C = 0$ (Section 7.1 relaxes this assumption). We assume CoCos payments decay at the same rate as the payments of non-contingent bonds ($\delta_C = \delta$).[6] We also assume suspended payments earn the risk-free rate ($r_C = r$) and thus there is no nominal debt forgiveness in CoCos. We discuss the effects of combining payment suspensions with debt forgiveness in Section 5.

Table 2 shows that, as anticipated by critics of CoCos, CoCos increase the default frequency, which is reflected in higher spreads. The increase in the default frequency implied by CoCos is due to the higher debt levels in the economy with CoCos (Table 2). To confirm this, Table 2 shows that if we do not allow debt to increase when we introduce CoCos, the introduction of CoCos lowers the default probability: When we impose a limit of 43 percent on the sum of non-contingent and CoCo debt (equal to the average debt level in the benchmark) in the economy with CoCos, this economy has a default frequency of 4.7 percent, which is lower than the default frequency of 6.2 percent in the benchmark. This indicates that preventing a debt increase upon the introduction of CoCos is crucial for reducing default frequency.

Figure 1 illustrates how CoCos also exacerbate the increase in the default probability after risk-premium shocks. This occurs because with CoCos, the government exits high-risk-premium (payment-suspension) periods with higher debt levels (Figure 1).[7] Consistently, Table 2 shows that CoCos exacerbate the spread increase triggered by the risk-premium shock. More generally, Figure 2 shows that CoCos increase the response of the sovereign spread to a negative income shock. Thus, CoCos increase the sovereign spread volatility (Table 2).

[6]Assuming that CoCos payments decay at the same rate of the payments of non-contingent bonds implies that CoCos have a longer duration than non-contingent bonds (Table 2) because we expect to postpone CoCos payments. Assuming a longer duration of sovereign bonds exacerbates the inefficiencies resulting from the government's lack of commitment to future borrowing (Hatchondo et al., 2020a). To assure our findings are not significantly contaminated by the assumed duration of CoCos, we run our experiments with different durations and find equivalent results. For example, changing δ_C so that CoCos and non-contingent bonds have the same duration does not affect our results significantly, indicating that the higher default probability with CoCos (Table 2) is not the result of a assuming a longer debt duration. See also footnote 7.

[7]Figure 1 also illustrates how the government may want to issue non-contingent debt to buyback CoCos when the risk premium is high. Allowing for buybacks does not significantly affect our findings: When we simulate the CoCos economy without allowing the government to buy back debt, we find almost identical results. Furthermore, when we simulate the economy with only CoCos (and thus the government cannot issue non-contingent debt to buy back CoCos), 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).

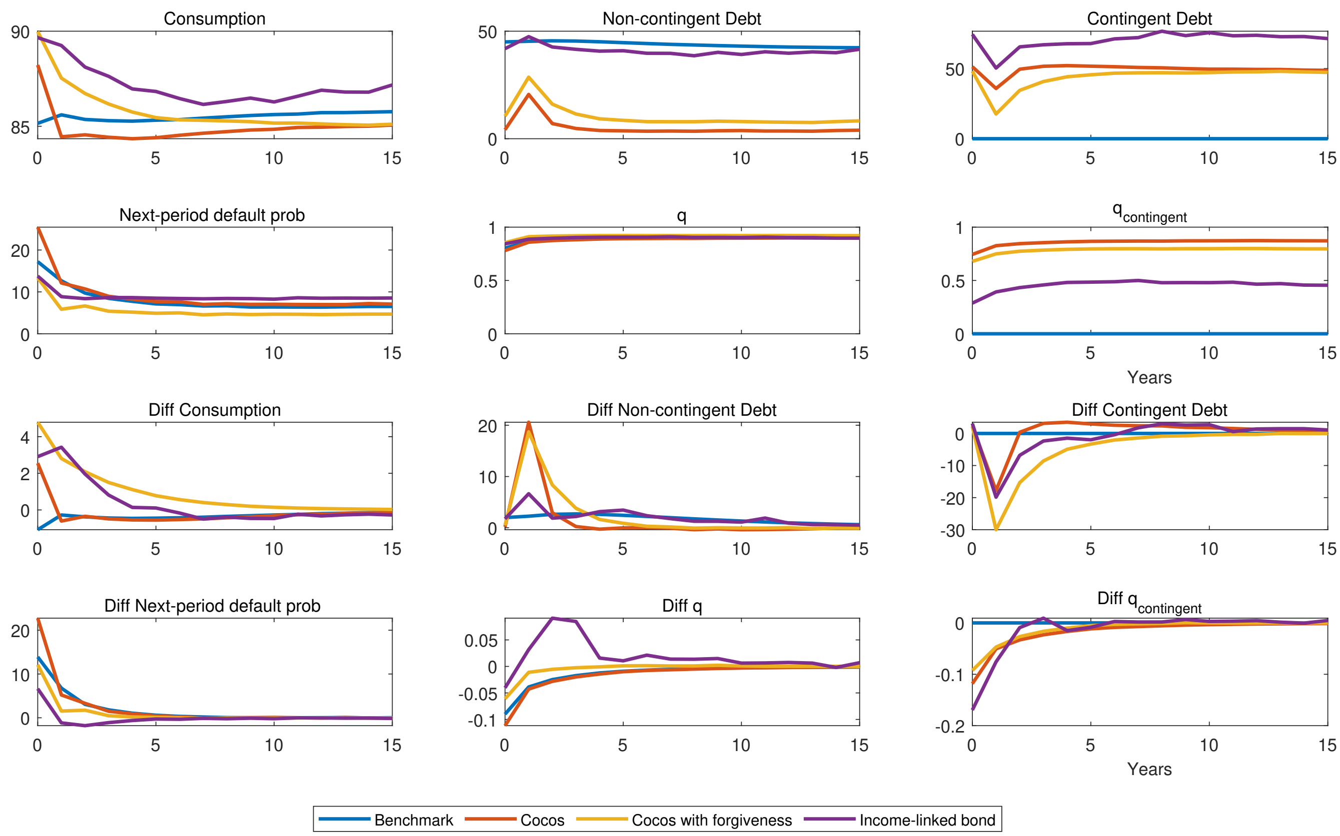


Figure 1: Impulse response functions. Behavior of key variables after each economy with the average debt and income levels is jointly hit by a risk-premium shock and a negative one-standard-deviation income shock (all shocks are zero after that; the risk-premium shock lasts for one year and income recovers following its law of motion). Top panels present the variables in levels. Bottom panels present percentage-point differences with the value of the variable for average income and debt levels and without a risk-premium shock. Consumption and debt are divided by current income. Consumption and debt are presented as a percentage of mean income. The next-period default probability is presented as percentage points. Bond prices correspond to the end-of-period equilibrium debt level. "Cocos with forgiveness" values correspond to the optimal debt forgiveness presented in Section 5.

CoCos exacerbate the spread increase triggered by the risk-premium shock even though CoCos eliminate the defaults triggered by these shocks (Table 2). Figure 3 illustrates how even when the postponement of CoCos payments would prevent a default, the government exits the postponement period with a higher debt level and default probability.

As expected by proponents of CoCos and illustrated in the top-left panel of Figure 1, CoCos allow the government to overcome the decline in consumption triggered by the risk-premium shock. Table 2 shows that consumption volatility is lower in the economy with CoCos.

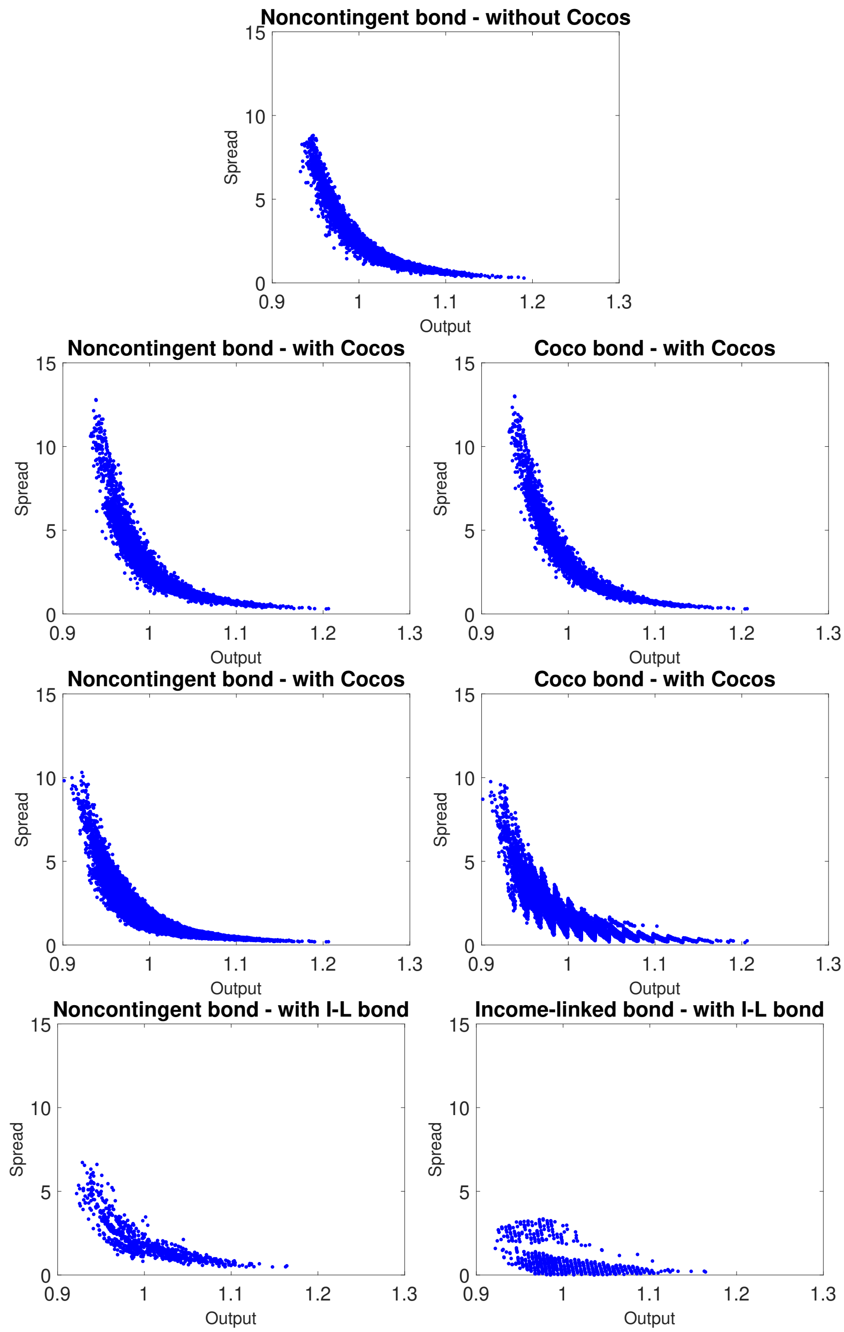


Figure 2: Sovereign spreads in the simulations. The first row corresponds to the benchmark, the second row corresponds to the economy with no-forgiveness CoCos (Section 4). The third row corresponds to debt-forgiveness CoCos (Section 5). The fourth row corresponds to income-linked bonds (Section 6).

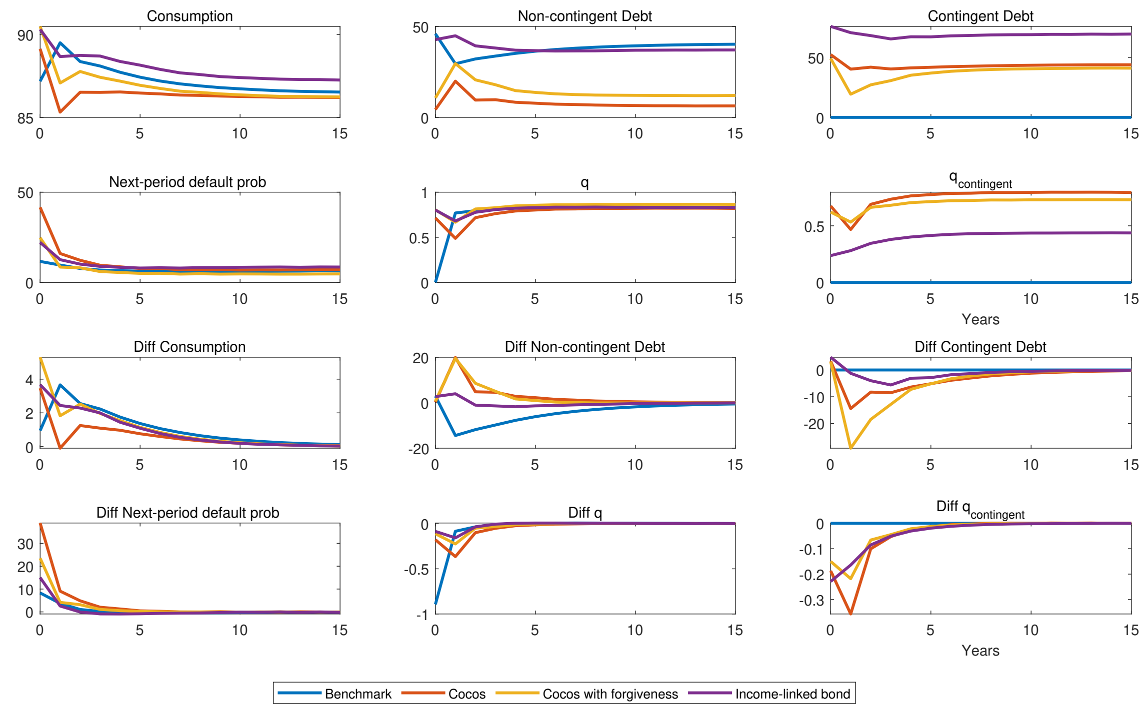


Figure 3: Impulse response functions for a shock that triggers a default only without CoCos. Behavior of key variables after each economy with the average debt and income levels is jointly hit by a risk-premium shock and a negative two-standard-deviation income shock (all shocks are zero after that; the risk-premium shock lasts for one year and income recovers following its law of motion). Top panels present the variables in levels. Bottom panels present percentage-point differences with the value of the variable for average income and debt levels and without a risk-premium shock. Consumption and debt are divided by current income. Consumption, debt, and the next-period default probability are presented as percentage points. Bond prices correspond to the end-of-period equilibrium debt level. "Cocos with forgiveness" values correspond to the optimal debt forgiveness presented in Section 5.

4.1 Welfare

Figure 4 shows that introducing CoCos increases welfare.[8] Welfare losses implied by the higher default frequency with CoCos are overcome by welfare gains that arise from the initial consump-

[8] 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 "CoCos" refers to the economy with CoCos. Thus, a positive welfare gain means that agents prefer the economy with CoCos.

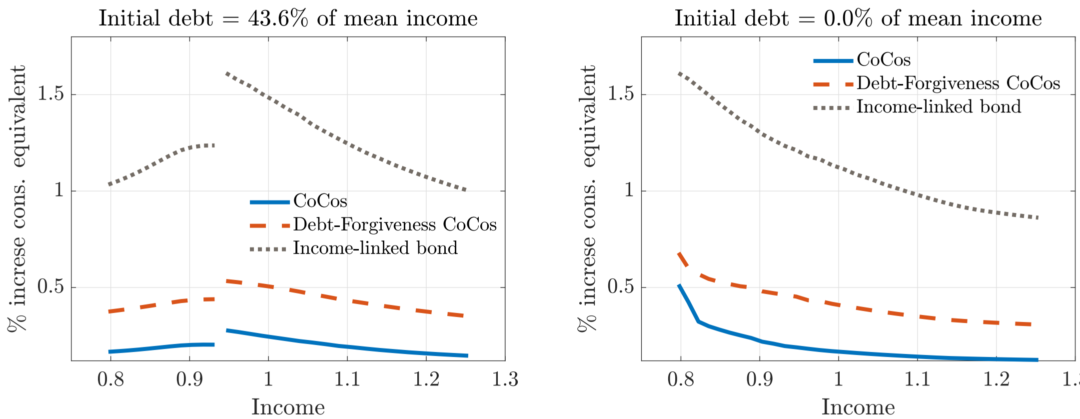
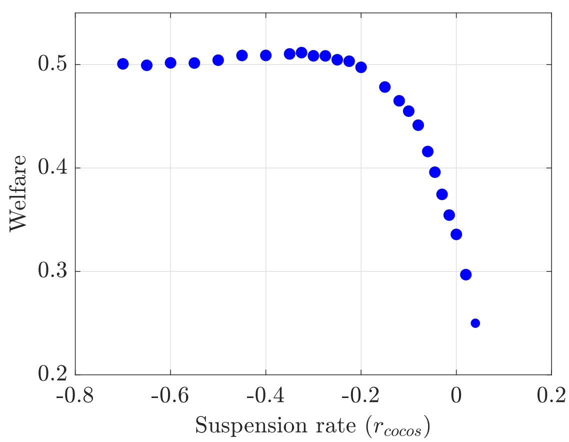


Figure 4: Welfare gains from introducing state-contingent debt instruments. The figure assumes a high risk-premium ($p = p_H$) but welfare gains are very similar in states with a low risk-premium.

tion increase triggered by the government's ability to sustain higher levels of indebtedness with CoCos, and from the improved consumption smoothing. Since in the standard default model, the effect of lowering consumption volatility on welfare is small, gains from tilting consumption account for the bulk of the welfare gains from introducing CoCos.

Welfare gains reported in Figure 4 are computed using the government's discount factor, which one could argue is lower than the representative household's discount factor. To gauge the effect of the government's impatience, we also compute welfare gains with a discount factor of 0.96, which could represent the discount factor of the representative household. We find that this reverts the welfare gains from introducing CoCos reported in Figure 4, resulting in small welfare losses. Intuitively, compared with the impatient government, the more patient household values less that the introduction of CoCos allows the government to tilt consumption, and suffers more from the higher default frequency in future periods implied by CoCos. The larger welfare gains from introducing debt-forgiveness CoCos that lower the default probability (Section 5) or income-linked bonds that greatly improve consumption smoothing (Section 6) survive the use of a higher discount factor.



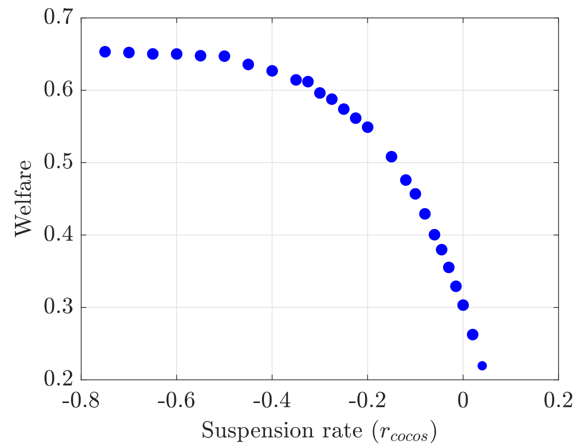


Figure 5: Optimal CoCos debt forgiveness. The left (right) panel considers the economy with shocks to the risk premium (the government's financing needs; Section 7.3).

5 Debt-Forgiveness CoCos

Following existing proposals, the previous section assumes that after a negative shock, CoCos payments are suspended but there is no nominal debt forgiveness ($r_C = r$). Figure 5 shows that the government would benefit from CoCos that provide debt forgiveness: The optimal growth rate of suspended CoCos payments is negative ($r_C = -0.325$), indicating that it is optimal for CoCos to trigger debt forgiveness after adverse shocks.[9] Table 2 and Figures 1, 2, and 3 show that, in contrast with no-forgiveness CoCos ($r_C = r$), CoCos with the optimal debt forgiveness ($r_C = -0.325$) result in a significantly lower default probability reflected in lower spreads, in a smaller default probability and spread increase triggered by risk-premium shocks, and in a weaker response of sovereign spreads to income shocks reflected in a lower spread volatility.

The key difference between no-forgiveness and debt-forgiveness CoCos is that only the latter generate a lower debt level after negative risk-premium shocks. This results in a significant decline in default risk and the associated sovereign spread after adverse shocks (Figure 1), in spite of an increase in the average level of indebtedness (Table 2). In contrast, because of postponed payments, no-forgiveness CoCos generate an increase in the debt level, default risk, and sovereign spread after negative shocks (Figures 1 and 3).

[9]Welfare gains from increasing debt forgiveness level off after sufficient debt relief is provided. This occurs because the government can always lower the level of debt forgiveness in its portfolio by issuing fewer CoCos if they provide too much debt forgiveness.

Table 2 also shows that debt-forgiveness CoCos improve consumption smoothing implying a lower consumption volatility. Figures 1 and 3 illustrate how complementing the suspension of debt payments in CoCos with debt forgiveness allows for higher consumption after the risk-premium shock. Recall that in response to the risk-premium shock, no-forgiveness CoCos increase the level of debt thus increasing the default probability and the spread. This impairs the government's ability to borrow for consumption smoothing. In contrast, debt-forgiveness CoCos lower the level of debt, the default probability, and the spread, improving the government's ability to borrow for consumption smoothing.

Debt forgiveness in CoCos is often resisted because it is expected it would increase the interest rate governments pay when issuing debt (Ross and Ulukan, 2020). Figures 1 and 3 illustrate how this is indeed the case in the simulations, as reflected in the lower price of debt-forgiveness CoCos. However, to the extent lower bond prices reflect a fair compensation for the lower expected payments because of debt forgiveness, this is inconsequential for welfare. In contrast, the lower default probability attained because of debt forgiveness and reflected in lower spreads results in welfare gains.

6 Income-linked bonds

We next compare the effects of introducing CoCos with the effects of introducing income-linked bonds (which model the frequently-discussed GDP-linked bonds). We focus on the threshold bonds introduced by Roch and Roldán (2023): Coupons are only paid if income is above the mean. This reflects the typical design of state-contingent instruments that governments have used (Roch and Roldán, 2023).

Table 2 shows that, as with the introduction of CoCos, the introduction of income-linked bonds results in a higher default probability (implied by higher debt levels). This is in contrast with the results in studies that replace non-contingent bonds with income-linked bonds and find that economies with (only) income-linked bonds feature a significantly lower default probability even with higher debt levels (Hatchondo and Martinez, 2012; Hatchondo et al., 2016; Roch and

Roldán, 2023). Table 2 shows that even when income-linked bonds are available, the government chooses to issue significant amounts of non-contingent debt, which results in a higher default probability.

Compared with introducing CoCos, introducing income-linked bonds generates a larger decline in consumption volatility (Table 2), a larger decline in the response of spreads to adverse shocks (Figure 2), a larger consumption increase after adverse shocks (Figures 1 and 3), and larger welfare gains (Figure 4). This is natural since income shocks are more frequent than the risk-premium shocks that trigger CoCos relief.

7 Robustness

This section demonstrates the robustness of our main result: Introducing debt forgiveness greatly increases the effectiveness of sovereign CoCos. We first show that this is true if CoCos command a liquidity premium, with the government choosing to use significant levels of debt-forgiveness CoCos despite this premium. We then show that our results are also robust to changing key modeling choices for the costs and benefits of defaulting and to using a shock to the government's financing needs as the trigger for CoCos relief.

7.1 CoCos Liquidity premium

We next measure the effects of assuming that CoCos pay a liquidity premium over non-contingent bonds. Table 3 presents results for a liquidity premium for CoCos of 35 basis points ($\ell^C = 0.0035$), the average liquidity premium for state-contingent debt instruments found by Moretti (2020).

Table 3 shows that a liquidity premium would significantly reduce the government's willingness to use CoCos. However, the table also shows that CoCos still play a significant role, and even more so in the case of debt-forgiveness CoCos ($r_C = -0.325$), which the government chooses to use heavily despite the liquidity premium. The introduction of debt-forgiveness CoCos still reduces the default frequency significantly despite higher debt levels, and improves consumption

	(1) CoCos $\ell^C = 0.0035$	(2) $\ell^C = 0.0035$ $r_C = -0.325$	(3) Bench. barg.	(4) CoCos barg.	(5) Barg. $r_C = -0.48$	(6) Bench. g shock	(7) CoCos g shock
			Targeted moments (in the benchmark)				
Mean debt/y (%)	37.2	26.0	43.1	2.4	6.6	37.1	3.0
Mean r_s (%)	2.3	1.7	2.5	4.7	1.6	2.0	2.1
Prob. high risk-premium shock (%)	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Lower y during high risk-premium (%)	4.2	4.8	4.7	4.7	5.0	4.3	4.7
$\sigma(c)/\sigma(y)$	0.98	0.95	1.00	0.9	1.2	1.2	1.1
Δ r_s with high-risk-premium shock	2.5	2.1	1.9	5.0	0.7	2.7	3.9
Duration	3.0	3.1	5.8	5.3	6.1	3.1	3.1
			Other moments				
Mean contingent debt/y (%)	9.2	26.6	*n.a.*	60	46.0	*n.a.*	45.1
Mean contingent r_s (%)	2.8	1.9	*n.a.*	4.6	1.1	*n.a.*	2.7
Defaults per 100 years	6.3	4.5	2.0	3.7	1.3	6.4	7.7
Duration contingent debt	3.6	3.0	*n.a.*	6.5	4.9	*n.a.*	3.6
$\sigma(r_s)$	1.4	1.2	1.0	2.3	0.7	1.4	1.7
$\sigma(r_s)$ contingent debt	1.3	1.1	*n.a.*	2.2	0.5	*n.a.*	1.8
$\rho(c, y)$	0.95	0.90	0.95	0.90	0.4	0.92	0.90
Δ contingent r_s when $\Delta p_t = p_H$	2.1	2.0	*n.a.*	4.6	0.4	2.7	3.9
% of defaults triggered by $\Delta p_t = p_H$	0.9	0.1	7.3	0.0	0.0	1.1	0.0

Table 3: Robustness exercises.

smoothing. Overall, our main findings about the stronger performance of debt-forgiveness CoCos over no-forgiveness CoCos are robust to the introduction of a liquidity premium.

7.2 Endogenous recovery rate with an income cost of defaulting

This section shows that our findings are robust to changing our assumptions on the cost and benefits from defaulting. First, as is standard in the literature, we assume that a defaulting government is excluded from debt markets for a stochastic number of periods and suffers an income loss $\iota(y) = \lambda_0 y + \lambda_1 y^2$. At the beginning of each period after the default period, with probability ξ, a government in default restructures its defaulted debt and exits the default.

Second, we assume that the debt portfolio with which the government exits a default (and thus the recovery rate) is the outcome of a bargaining process between the sovereign and its creditors. Following Yue (2010), the debt portfolio with which the government exits a default is decided in a Nash bargaining game, where the threat point of the game is that the government stays in autarky forever (suffering the income cost of being in default) and that creditors do not recover anything from the defaulted debt. Defaults are settled by exchanging $\hat{b}^N(s)$ non-contingent bonds and $\hat{b}_C^N(s)$ CoCos for the defaulted bonds. The debt portfolio resulting from the Nash bargaining process solves:

$$\left(\hat{b}^N(s), \hat{b}_C^N(s)\right) = \underset{b,b_C}{Argmax} \left\{ \left[V^R(b, b_C, s) - V^A(y)\right]^{\phi} MV(b, b_C, s)^{1-\phi} \right\}, \tag{8}$$

where ϕ denotes the government's bargaining power,

$$V^A(y) = u\left(y - \iota(y) - g\right) + \beta \mathbb{E}_{s'|s}\left[V^A(y')\right]$$

denotes the government's continuation value under autarky, and

$$\begin{aligned} MV(b, b_C, s) =& b\left[\delta + (1-\delta) q\left(\hat{b}\left(b, b_C, s\right), \hat{b}_C\left(b, b_C, s\right), s\right)\right] \\ &+ b_C \ \left[1 - \mathcal{I}(p)\right]\left[\delta_C + (1-\delta_C) q_C\left(\hat{b}\left(b, b_C, s\right), \hat{b}_C\left(b, b_C, s\right), s\right)\right] \\ &+ b_C \mathcal{I}(p) e^{r_C} q_C\left(\hat{b}\left(b, b_C, s\right), \hat{b}_C\left(b, b_C, s\right), s\right) \end{aligned} \tag{9}$$

denotes the market value of the debt portfolio (b, b_C). The first line of equation (9) represents the market value of the bonds with non-contingent payments. The second line of equation (9) represents the market value of a CoCo bond if there is no payment suspension. The third line of equation (9) represents the market value of CoCo bonds if there is a payment suspension.

Note from equation (8) that the debt portfolio with which the government exits the default does not depend on the debt portfolio the government defaulted on. This is an extension of the result presented by Yue (2010), who shows that in a model with one debt instrument, the post-default debt level does not depend on the debt level the government defaulted on. In our model with two debt instruments, not only the debt level but also the composition of the debt portfolio is irrelevant for determining the debt portfolio with which the government exits the default. As explained by Yue (2010), at the moment of the debt renegotiation, bygones are bygones.

It remains to specify how the debt portfolio with which the government exits the default is distributed among the holders of non-contingent bonds and CoCos that were in default. Suppose that in state s, the defaulted portfolio (b, b_C) is restructured with an exit portfolio $\left(b^N, b_C^N\right)$. We first divide the exit portfolio $\left(b^N, b_C^N\right)$ between holders of non-contingent bonds (as a group) and holders of CoCos (as a group). We assume that holders of non-contingent bonds receive a fraction $\theta(b, b_C, s)$ of the exit portfolio $\left(b^N, b_C^N\right)$. This is, holders of non-contingent bonds receive $\theta(b, b_C, s)b^N$ non-contingent bonds and $\theta(b, b_C, s)b_C^N$ CoCos. Holders of CoCos receive $[1-\theta(b, b_C, s)]b^N$ non-contingent bonds and $[1-\theta(b, b_C, s)]b_C^N$ CoCos. Therefore, holders of non-contingent bonds receive a fraction $\theta(b, b_C, s)$ of the market value of the exit portfolio $MV(b^N, b_C^N, s)$, and holders of CoCos receive a fraction $[1-\theta(b, b_C, s)]$ of $MV(b^N, b_C^N, s)$.

Among holders of defaulted non-contingent bonds (CoCos), the portfolio of bonds they receive in the restructuring, $\left(\theta(b, b_C, s)b^N, \theta(b, b_C, s)b_C^N\right)$ $\left(\left([1-\theta(b, b_C, s)]b^N, [1-\theta(b, b_C, s)]b_C^N\right)\right)$ is divided proportionally according to the number of non-contingent bonds (CoCos) they hold. This is, the holder of one defaulted non-contingent bond receives an exit portfolio $\frac{\theta(b,b_C,s)}{b}\left(b^N, b_C^N\right)$, and the holder of one defaulted CoCo receives an exit portfolio $\frac{1-\theta(b,b_C,s)}{b_C}\left(b^N, b_C^N\right)$.

Therefore, the holder of one non-contingent bond (CoCo) receives a faction $\theta(b, b_C, s)/b$ ($[1-\theta(b, b_C, s)]/b_c$) of the market value of the portfolio of bonds received in the restructuring $MV(b^N, b_C^N, s)$. In anticipation of the outcome in the restructuring period, the price of a non-contingent bond in default satisfies

$$q^D(b', b_C', s) = \mathbb{E}_{s'|s}\left[M(\varepsilon', p)\left[\overbrace{(1-\xi)q^D(b', b_C', s')}^{\substack{\text{Expected price when}\\ \text{government remains in default}}} + \overbrace{\xi\frac{\theta(b', b_C', s')}{b'}MV(\hat{b}^N(s'), \hat{b}_C^N(s'), s')}^{\substack{\text{Expected price when}\\ \text{the government exits the default}}}\right]\right], \tag{10}$$

and the price of a Coco in default satisfies

$$q_C^D(b', b_C', s) = \mathbb{E}_{s'|s}\left[M^C(\varepsilon', p)\left[(1-\xi)q^D(b', b_C', s') + \xi\frac{1-\theta(b', b_C', s')}{b_C'}MV(\hat{b}^N(s'), \hat{b}_C^N(s'), s')\right]\right]. \tag{11}$$

We assume the fraction of the post-restructuring portfolio received by holders of non-contingent bonds, $\theta(b, b_C, s)$, is determined by the weight of the market value these bonds would have in default $bq^D(b, b_C, s)$ in the total market value of debt in default, $bq^D(b, b_C, s) + b_C q_C^D(b, b_C, s)$:

$$\theta(b, b_C, s) = \frac{bq^D(b, b_C, s)}{bq^D(b, b_C, s) + b_C q_C^D(b, b_C, s)}.$$

We define the recovery rate for debt in default $\alpha(b, b_C, s)$, which we use in the calibration, as the weighted sum of the fractions of non-contingent bonds and CoCos recovered in the restructuring, b^N/b and b_C^N/b_C, with the weight of non-contingent bonds given by $\theta(b, b_C, s)$:

$$\alpha(b, b_C, s) = \theta(b, b_C, s)\frac{\hat{b}^N(s)}{b} + [1 - \theta(b, b_C, s)]\frac{\hat{b}_C^N(s)}{b_C}.$$

In this alternative environment with endogenous post-restructuring debt portfolios, the continuation value for a government in default is given by:

$$V^D(b, b_C, s) = u\left(y - \iota(y) - g\right) + \beta \mathbb{E}_{s'|s}\left[(1 - \xi)V^D(b, b_C, s) + \xi V^R(\hat{b}^N(s'), \hat{b}_C^N(s'), s')\right].$$

In a period without default, the price of a non-contingent bond is given by

$$\begin{aligned} q(b', b'_C, s) &= \mathbb{E}_{s'|s}\Big[M(\varepsilon', p)\Big[\hat{d}\left(b', b'_C, s'\right)q^D(b', b'_C, s') \\ &+ \Big[1 - \hat{d}\left(b', b'_C, s'\right)\Big]\Big[\delta + (1 - \delta)q\left(\hat{b}\left(b', b'_C, s'\right), \hat{b}_C\left(b', b'_C, s'\right), s'\right)\Big]\Big]\Big], \end{aligned}$$

and the price of a CoCo is given by

$$\begin{aligned} q_C(b', b'_C, s) &= \mathbb{E}_{s'|s}\Big[M^C(\varepsilon', p)\Big[\hat{d}\left(b', b'_C, s'\right)q_C^D(b', b'_C, s') \\ &+ \Big[1 - \hat{d}\left(b', b'_C, s'\right)\Big]\Big[[1 - \mathcal{I}(p')]\Big[\delta_C + (1 - \delta_C)q_C\left(\hat{b}\left(b', b'_C, s'\right), \hat{b}_C\left(b', b'_C, s'\right), s'\right)\Big] \\ &+ \mathcal{I}(p')e^{r_C}q_C\left(\hat{b}\left(b', b'_C, s'\right), \hat{b}_C\left(b', b'_C, s'\right), s'\right)\Big]\Big]\Big]. \end{aligned}$$

The value function of a government at the beginning of each period and the value function of repayment are computed as in the model with an exogenous recovery rate.

Using the model without CoCos, the parameter values for the government's risk aversion ($\gamma = 2$), the cost of defaulting ($\lambda_0 = -2.3$ and $\lambda_1 = 2.485$), the probability of exiting default ($\xi = 0.33$), the rate of decay of debt payments ($\delta = 0.117$), the lenders' risk premium shock ($p_H = 15.6$), and the government bargaining power ($\phi = 0.904$) are calibrated targeting a volatility of consumption equal to the volatility of income, a mean spread of 2.4 percent, a mean public debt to GDP ratio of 43.5 percent, a default duration of three years (within the range of targets used in the literature), a debt duration of 6 years (within the range of targets used in the literature), a spread increase during high risk-premium episodes of 2 percentage points, and an average recovery rate for defaulted debt of 63 percent. Table 3 shows that the simulations (benchmark bargaining) match these targets well.

Table 3 also shows that our findings are robust to the modifications of the model presented in this section. The introduction of (no-forgiveness) CoCos eliminates defaults triggered by risk-premium shocks but results in higher debt levels and a higher default probability. In contrast, the introduction of debt-forgiveness CoCos (with the optimal $r_C = 0.48$) reduces the default probability.

7.3 An alternative trigger for the payment-suspension clause

To illustrate the robustness of our findings to the type of payment-suspension trigger, we study shocks that increase the government's financing needs (for instance, because of natural disasters) and shut off the risk-premium shock ($p_H = 0$). Formally, we assume that government expenditures g may take a low or a high value: $g_t \in \{g_L, g_H\}$. The shock g_t follows a Markov process with the same structure of the risk-premium shock (this is, we assume $\pi_0 = 0.38$, $\pi_1 = 38$, and $\pi_{HL} = 0.8$). We set the low level of the expenditure shock to the value used in the baseline calibration: $g_L = 0.12$. The high level of the expenditure shock captures a 10 percent of average income increase in public expenditures ($g_H = 0.22$), which is consistent with the size of shocks reported by Bova et al. (2016). The rest of the parameters in the model are the same as the ones presented in Section 3 and Table 1.

Table 3 and the right panel of Figure 5 show that our findings are robust to changing the nature of the payment-suspension trigger we consider. Table 3 shows that CoCos eliminate defaults triggered by an increase in financing needs, reduce consumption volatility, but they increase the overall default frequency. The right panel of Figure 5 shows that welfare gains from introducing CoCos can be increased significantly if Cocos also trigger debt forgiveness.

8 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 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 the effectiveness of CoCos is enhanced if adverse shocks trigger debt forgiveness. In contrast with no-forgiveness CoCos, debt-forgiveness CoCos lower the default frequency. We show that these findings are robust to different model specifications.

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