Default and Interest Rate Shocks: Renegotiation Matters*

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Abstract

We develop a sovereign default model with debt renegotiation in which interest-rate shocks affect default incentives through two mechanisms. The first is the standard mechanism through which higher rates tighten the budget constraint. The second rests on how risk-free rates affect lenders' opportunity cost of holding delinquent debt. When rates are high, this cost increases and lenders accept larger haircuts, which makes default more attractive ex-ante. We use the model to study the 1982 Mexican default, which followed a large increase in US interest rates. Our novel renegotiation mechanism is key for reconciling sovereign default models with the narrative that US monetary tightening triggered the crisis.

Keywords: Sovereign default, Renegotiation, Interest rate shocks.

JEL Codes: F34, F41

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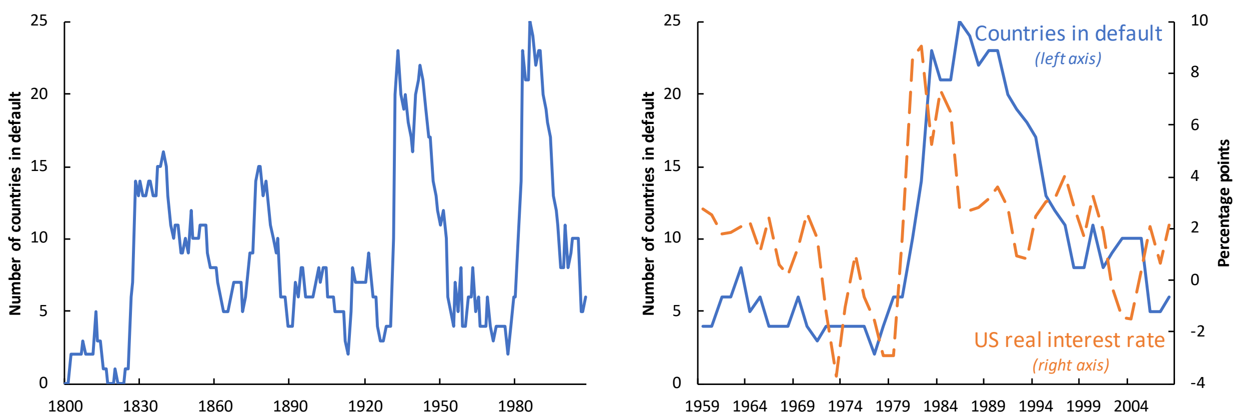
1 Introduction

The 1980s featured the most wide-spread sovereign debt crisis in history. The left panel of Figure 1 shows how it compares with other difficult periods such as the Napoleonic Wars, World Wars I and II, and the Great Depression. Starting in 1982 with the Mexican default, the crisis reached a peak of 25 countries suspending some or all debt payments by 1985. There were on average 19 countries in default in each year during the decade, out of which 11 were from Latin America. Due to its depth and length, the economic collapse that accompanied the debt crisis during the 1980s is referred to as the "lost decade" in Latin America.

Figure 1: Debt crises and interest rates, 1980s case



The data of countries in default are from Reinhart and Rogoff (2009). The US real interest rate is the annual yield on 1-year US treasury bonds minus observed inflation.

The crisis was preceded by aggressive interest rate increases in the U.S. by the then Chairman of the Federal Reserve Paul Volcker, which were intended to tame rising inflation. The right panel of Figure 1 shows how real interest rates in the U.S. were a leading indicator of the number of countries in default during the 1980s, with the initial rate-hike being shortly followed by a cascade of sovereign defaults.

This "Volcker shock" is often credited for being the main trigger of the crisis. The usual narrative focuses on the direct impact that higher interest rates had on debt service, since most debt had been contracted at floating rates in foreign currency (see for instance Ocampo (2014) and Tourre (2017)). We argue that such an interest rate shock has an additional indirect effect on default incentives through the terms that emerge from an eventual debt renegotiation.[1]

We develop a stylized model of sovereign default and renegotiation, and show that governments get more beneficial outcomes when interest rates are high.[2] The intuition is simple: lenders' opportunity cost of holding delinquent debt is higher when risk-free rates are high, so they are willing to accept a smaller recovery in order for payments to resume. We compare two mechanisms through which risk-free interest rates affect default incentives ex-ante. The first—which we call the *standard mechanism*—works through lenders discounting future debt payments at a higher rate. This directly lowers the market price of government debt, which in turn makes servicing current debt more expensive. The second—which we call the *renegotiation mechanism*—refers to how a high risk-free rate improves the expected terms for the government of a future renegotiation, which in turn increases the value of defaulting in the present. In addition, these expectations also decrease the market price of government debt in good standing, since lower payments from future recovery after default are also priced in. Thus, while the *standard mechanism* only decreases the value of repaying the debt, the *renegotiation mechanism* both increases the value of defaulting and decreases the value of repaying. This intuition suggests that renegotiation considerations play a more important role when interest rate shocks trigger default events, which is what we explore in our quantitative exercise.

We build on our stylized environment to develop a quantitative sovereign default model with endogenous debt renegotiation and persistent shocks to the risk-free interest rate.[3] We calibrate the model to the 1982 Mexican default. We use data prior to 1982 to calibrate the parameters that govern the income process, borrowing, and default probabilities. Importantly, we calibrate the parameters that govern the bargaining game so that the average haircut generated endogenously by the model equals the haircut to Mexican debt under the Brady plan. We find that, in the ergodic distribution, 22 percent of interest rate hikes trigger a default event. In order to compare the relevance of both mechanisms we consider two counterfactual economies that feature a fixed debt haircut instead of endogenous renegotiation. For the first, we consider a haircut of 100 percent,

[1] As documented by Sturzenegger and Zettelmeyer (2008) and Benjamin and Wright (2009), among others, defaulting countries and their lenders negotiate reductions on the defaulted debt.

[2] Our result is consistent with Guimaraes (2011), who proves for in a similar simple environment that shocks to risk-free interest rates have a larger impact on the incentive compatible level of debt, which directly affects the extent of debt relief.

[3] Guimaraes (2011) shows that the effect of interest rate shocks on default incentives is increasing in the persistence of the shocks, which stresses the importance of dynamic considerations during the process of debt renegotiation.

which would be akin to the canonical models in the literature in which governments are readmitted to financial markets with no debt (see Arellano (2008), Aguiar and Gopinath (2006), Chatterjee and Eyigungor (2012)).[4] For the second, we consider a fixed haircut equal to the average targeted in the benchmark calibration. In these two counterfactual economies, the fraction of interest rate hikes that trigger a default event are 0.06 and 0.13, respectively. We draw two conclusions from these exercises. The first is that, absent the possibility of some debt recovery, interest rate hikes have a small effect on default incentives. This implies that the usual narrative of the "Volcker shock" triggering the Mexican default in 1982 solely through higher interest costs is unlikely. Our second conclusion is that, in the presence of some debt recovery after default, the *renegotiation mechanism* described above (i.e. the government expecting favorable renegotiation terms if interest rates remain high) accounts for roughly half of the default risk generated by interest rate hikes.

Related literature.—This paper is closely related to the literature that studies debt renegotiation in quantitative sovereign default models. Yue (2010) develops a model in which debt renegotiation happens after a default has occurred. An important difference between her environment and ours is the set of assumptions regarding the outside options in the renegotiation game. She assumes that if a renegotiation attempt were unsuccessful then the government would face indefinite autarky and lenders would recover nothing. We relax this by, instead, assuming that the alternative to a present renegotiation outcome is to wait for a future one. This increases the outside value of lenders as long as they have some bargaining power. Moreover, this outside value is directly affected by the level of the risk-free interest rate in the renegotiation period, which is crucial to our *renegotiation mechanism*. In related papers, Benjamin and Wright (2009), Pitchford and Wright (2011), Bai and Zhang (2012), Benjamin and Wright (2018), and Asonuma and Joo (2020) study delays in sovereign debt renegotiation. They develop environments in which delays arise endogenously as strategies in the bargaining game to restructure debt. Similarly, Dvorkin, Sanchez, Sapriza, and Yurdagul (2023) study sovereign debt restructurings in a model in which governments and lenders make alternating offers and endogenous delays are possible through taste shocks that are realized after these offers have been made. A key difference between our model

[4] In a recent paper, Arellano, Mateos-Planas, and Rios-Rull (2022) study an environment in which a government can choose to default on a fraction of its debt. The main difference between their model and the existing literature on debt renegotiation that we review below is that they allow for the government to continue to borrow while in partial default.

and theirs is that our assumptions prevent delays from happening in equilibrium. What is essential for our results is the threat of delay. Even if neither player chooses to delay in equilibrium, the fact that they could affects the outcome of the bargaining game. These assumptions provide a great deal of simplification and allow us to focus on the role of risk-free interest rates. Hatchondo, Martinez, and Sosa-Padilla (2014) develop a model of voluntary debt exchanges in which the government and lenders can choose to reduce the face value of the debt before a default occurs. These exchanges are mutually beneficial and happen in equilibrium when the stock of debt is to the right side of the Laffer curve. Unlike them, we do not allow for debt renegotiation to prevent a default in our model. Asonuma and Trebesch (2016) document that roughly 38 percent of debt restructurings happen preemptively, have lower haircuts, and are quicker to negotiate. We chose to focus on ex-post restructuring out of simplicity in order to highlight the role of risk-free interest rates. The forces that we identify would be also present in any restructuring that occurs ex-ante. Mihalache (2020) documents that debt relief programs are mostly implemented through maturity extensions, rather than through reductions to the face value of debt. The essence of our results would not change if maturity extensions were included in the renegotiation game. Whether it is through a higher debt haircut or through a more convenient maturity extension, our main result about the government getting a more favorable outcome with high rates would still hold.

This paper also contributes to the literature that studies the effect of shocks to risk-free interest rates on default risk. Our work is closely related to Guimaraes (2011), who develops a stylized model of debt renegotiation similar to ours and uses it to compare the role that income and interest rate shocks have on debt relief. One of his findings is that the increase in world interest rates at the beginning of the 1980's can solely account for over half of the debt forgiveness obtained by the main Latin American countries through the Brady plan. Our quantitative findings echo his and highlight the ex-ante role of these expected outcomes on the initial default decisions. Moreover, we disentangle the different channels through which the interest rate shock affected default incentives. Singh (2020) develops a model to study clustered defaults and uses it to analyze the 1980's debt crisis. He finds that the Volcker shock was not a decisive factor for the clustered defaults and, instead, global shocks that jointly affected income in the defaulting countries played a major role. However, his model does not feature debt renegotiation and, thus, his findings with such a model are consistent with our results. Johri, Khan, and Sosa-Padilla (2022) incorporate an estimated time-varying process for the risk-free interest rate to a model of sovereign default. They find that shocks to the interest rate have a sizable impact on sovereign spreads, even in the absence of renegotiation. An important feature of their model is the time-varying variance of the risk-free rate since the large quantitative effect is mostly driven by shocks during periods of high volatility. In our model the volatility of the risk-free rate is fixed. However, as long as risk-free rates are persistent, the *renegotiation mechanism* that we identify is an amplifier of the effect of interest rate shocks, regardless of their variance.

Layout.—Section 2 presents a "one-shot" model of sovereign default and renegotiation which highlights the intuition behind our main result. Section 3 presents the general model and the quantitative exercises. Section 5 concludes.

2 One-shot model

This model presents a one-shot game of sovereign default. An impatient government faces a stochastic stream of income and issues short-term defaultable debt. The government is able to sustain positive debt levels due to the threat of financial autarky for a stochastic number of periods and a dead-weight income loss during exclusion. After exclusion, the government and the lenders negotiate over a flow of income (without the dead-weight loss) that remains constant from that period on and the game ends.

Figure 2: Income throughout the game

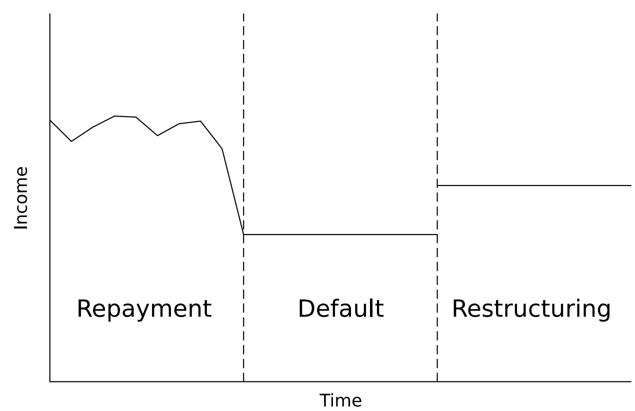


Figure 2 illustrates the evolution of income over time throughout the game. We use this game to highlight how debt renegotiation affects default incentives ex-ante and, crucially, how the level of the risk-free interest rate—which scales the lenders' outside option—affects the negotiated terms.

Environment.—Time is discrete and runs forever. There is a small-open economy populated by a government with preferences for streams of consumption represented by $U_t\left(\{c_s\}_{s=t}^{\infty}\right) = \mathbb{E}_t\left[\sum_{s=t}^{\infty}\beta^{s-t}u\left(c_s\right)\right]$ where $\beta \in (0,1)$ is a discount factor, and u is continuously differentiable, strictly increasing, striclty concave, $\lim_{c\to 0}u\left(c\right) = -\infty$ and $\lim_{c\to 0}u'\left(c\right) = \infty$. Each period, the government receives a stochastic endowment $y_t \in (0,2)$ which is iid over time with $\mathbb{E}\left[y_t\right] = 1$ and CDF $F\left(y\right)$. The sovereign can issue one-period non-contingent debt b_{t+1} in international financial markets. Debt is purchased by a measure 1 of identical risk-neutral lenders with deep pockets who have access to a risk-free bond that pays a fixed interest rate r. At the beginning of each period, the government observes the realization of y_t and decides whether to repay its outstanding debt. If the government chooses to default, then it is immediately excluded from financial markets and income is $\lambda < 1$. After default, the government remains in financial autarky and income continues to be λ

until an opportunity to renegotiate arises, which happens with probability θ. After renegotiation, the government receives a constant stream of income $\mathbb{E}[y_t] = 1$ forever, out of which it consumes $1-\rho^*$ in each period. The value ρ^* is captured by the lenders (i.e. it cannot be defaulted on) and is determined in a negotiation period through Nash bargaining. We assume that either party can choose to reject a proposed ρ^* and wait for a new renegotiation opportunity. In equilibrium, this never happens because the assumption of $\lambda < 1$ implies that there is a strictly positive surplus that can be split in the negotiation period. However, it is the possibility to reject and wait that allows the interest rate to have an important role in the determination of ρ^*.[5]

In order to define and characterize the equilibrium and its properties we proceed backwards. We first characterize the outcome of the renegotiation game ρ^* by guessing, and then verifying, that it is unique. Then, we use this characterization to define the equilibrium of the model.

Renegotiation.—Given a negotiated payment ρ^*, the value of the government in autarky after renegotiation is $V^A(\rho^*) = \frac{u(1-\rho^*)}{1-\beta}$. Thus, the value of the government in default, for a given ρ^*, is:

$$V^D(\rho^*) = \frac{u(\lambda)}{1-\beta(1-\theta)} + \frac{\beta\theta V^A(\rho^*)}{1-\beta(1-\theta)}. \tag{1}$$

Similarly, the value of a representative lender who holds defaulted bonds is:

$$Q^D(\rho^*) = \frac{\theta}{1+r} Q^A(\rho^*) + \frac{1-\theta}{1+r} Q^D(\rho^*) \tag{2}$$

where $Q^A(\rho^*) = \frac{1+r}{r}\rho^*$ is the value that lenders get after negotiating ρ^*. Plugging Q^A into the above equation we get that the value of holding defaulted bonds is

$$Q^D(\rho^*) = \frac{\theta}{r}\frac{1+r}{\theta+r}\rho^* \tag{3}$$

which is strictly decreasing in r. When an opportunity to renegotiate arises, lenders and the gov-

[5] In previous work, Yue (2010) assumes that renegotiation can take place only once after default, which implies that the outside value of lenders is to receive nothing. In such an environment, the renegotiation terms would not be affected by the level of the risk-free interest rate.

ernment engage in Nash bargaining. We define ρ^* as

$$\rho^* = \arg\max_{\tilde{\rho}} \left[S^{LEN}(\tilde{\rho})\right]^{\alpha} \left[S^{GOV}(\tilde{\rho})\right]^{1-\alpha} \tag{4}$$

$$s.t. \quad S^{GOV}(\tilde{\rho}) = V^A(\tilde{\rho}) - V^D(\rho^*) \geq 0$$

$$S^{LEN}(\tilde{\rho}) = Q^A(\tilde{\rho}) - Q^D(\rho^*) \geq 0$$

where $\alpha \in (0,1)$ is the lenders' bargaining power, and S^{GOV} and S^{LEN} are the surpluses of the government and the lenders, respectively. Note that both participation constraints consider the option to wait for a future renegotiation with outcome ρ^*. Assuming an interior solution, the first-order condition of the problem in (4) is

$$\alpha \left[\frac{u(1-\rho^*) - u(\lambda)}{1-\beta(1-\theta)}\right] = \frac{(1-\alpha)r}{\theta+r}\frac{u'(1-\rho^*)}{1-\beta}\rho^* \tag{5}$$

where we have used the definitions of V^A, V^D, Q^A, and Q^D above.

Lemma 1. If $\alpha \in (0,1)$, then there is a unique $\rho^* \in (0,1)$ that solves the bargaining problem in (4).

Proof: See Appendix A.□

The proof of Lemma 1 shows that, as long as both parties have some bargaining power, equation (5) has a unique solution in the interior of $(0,1)$. Intuitively, the assumption that $\lambda < 1$ implies that there is a strictly positive surplus to split. The fact that both parties can choose to delay renegotiation implies that, as long as $\alpha \in (0,1)$, both should get a strictly positive value out of the game. If the lenders have all the bargaining power, then they would offer $\rho^* = 1-\lambda$, which would leave the government indifferent between accepting and delaying forever. Similarly, if the government has all the bargaining power, then it will offer the lenders $\rho^* = 0$, which would leave them indifferent between accepting and delaying forever.

Given the above characterization of the renegotiation game, the value of the government in good financial standing is

$$V(b,y) = \max_{d\in\{0,1\}} \left\{dV^D(\rho^*) + (1-d)V^P(b,y)\right\} \tag{6}$$

where d is the default decision. The value of repaying the debt is

$$V^P(b,y) = \max_{b'} \{u(c) + \beta \mathbb{E}[V(b',y')]\} \tag{7}$$
$$s.t. \quad c + b \leq y + q(b')\,b'$$

where q is the price schedule for government bonds. Note that V^P is strictly increasing in y for any given b, so the default set $\mathcal{D}(b) = \{y \in (0,2)\,|V^P(b,y) < V^D(\rho^*)\}$ is characterized by a cutoff value $y^*(b)$ such that $V^P(b, y^*(b)) = V^D(\rho^*)$.

Equilibrium.—An equilibrium is value functions V and V^P, policy functions d and b', a price schedule q, and a renegotiation outcome ρ^* such that: (i) ρ^* solves the bargaining problem in (4); (ii) given ρ^* and q, the value and policy functions solve the functional equations (6) and (7); and (iii) given ρ^* and d, the price schedule is actuarially fair:

$$q(b') = \frac{1 - F(y^*(b'))}{1+r} + \frac{F(y^*(b'))}{1+r}\frac{Q^D(\rho^*)}{b'} \tag{8}$$

where y^* is the cutoff value implied by the policy function d.

2.1 Renegotiation matters

The risk-free rate r affects default incentives and borrowing choices ex-ante through two mechanisms. The first, which we call the *standard mechanism*, refers to how r affects the budget constraint of the government in repayment through its direct effect on how lenders discount (i.e. the denominators in equation (8)). The second, which we call the *renegotiation mechanism*, refers to how r affects the renegotiation outcome ρ^* and how, through it, it affects both the price schedule q in repayment and the value of defaulting.

Proposition 1. If $\alpha \in (0,1)$, then ρ^* is decreasing in r.

Proof: First, note that for r to have a meaningful role in renegotiation it is crucial that both parties have something to gain from the renegotiation process. As mentioned above, if $\alpha = 1$ then $\rho^* = 1 - \lambda$ and if $\alpha = 0$ then $\rho^* = 0$, regardless of the value of r. Rewrite equation (5) that characterizes ρ^* as

$$\frac{u(1-\rho^*) - u(\lambda)}{u'(1-\rho^*)\,\rho^*} = \frac{1-\alpha}{\alpha}\frac{1-\beta(1-\theta)}{1-\beta}\frac{r}{\theta+r}$$

and note that the left-hand-side is decreasing in ρ^* (this follows from u being increasing and concave). Also note that the right-hand-side is strictly increasing in r. If the interest rate increases then the right-hand-side increases, so ρ^* must decrease for the left-hand-side to increase too and the equality to hold.□

Recall that from equation (3) we get that the lenders' outside option is decreasing in r. Intuitively, a larger interest rate reduces the lenders' outside option because their opportunity cost of delaying payment increases. This makes them more willing to accept a lower ρ^* which improves the government's outcome after renegotiation. Hereafter we adopt the notation $\rho^*(r)$ and use Proposition 1 to analyze how the level of r affects default incentives ex-ante.

We can use (3) to write the value of repaying the debt as

$$V^P(b,y,r) = \max_{b'} \{u(c) + \beta \mathbb{E}[V(b',y',r)]\} \tag{9}$$

$$s.t. \quad c + b \leq y + \frac{1 - F(y^*(b',r))}{\underbrace{1+r}_{\text{standard mechanism}}} b' + \frac{\theta F(y^*(b',r))}{\underbrace{(\theta + r)\, r}_{\text{standard mechanism}}} \underbrace{\rho^*(r)}_{\text{renegotiation mechanism}}$$

where r affects the budget constraint by discounting the value of future debt payments (the *standard mechanism*) and by changing the value of ρ^* (the *renegotiation mechanism*). The cutoff y^* is defined by

$$V^P(b, y^*(b,r), r) = V^D(\rho^*(r)) \tag{10}$$

and depends on r directly through its effect on the budget constraint in V^P and indirectly through its effect on ρ^*.

Proposition 2. For any given b such that the repayment set is not empty, the default set is expanding in r.

Proof: Proposition 1 implies that V^D (defined in equation (1)) is increasing in r. Also, it is clear from equation (9) that V^P is decreasing in r. Then, for equation (10) to hold y^* must also increase as r increases.□

Proposition 2 provides the main result of this Section: default incentives are increasing in r. The intuition is that high interest rates improve the government's value of defaulting because they improve the terms that it would get out of an eventual renegotiation. Absent endogenous renegotiation, the interest rate would still affect default incentives, but only through the *standard* *mechanism*. Suppose a counterfactual economy in which debt recovery is $\rho^* = \kappa$, where $\kappa \in (0,1)$ is some fixed number. Then, equation (9) becomes

$$V^P(b,y,r) = \max_{b'} \{u(c) + \beta \mathbb{E}[V(b',y',r)]\} \tag{11}$$
$$s.t. \quad c + b \leq y + \frac{1 - F(y^*(b',r))}{\underbrace{1+r}_{\text{standard mechanism}}} b' + \frac{\theta F(y^*(b',r))}{\underbrace{(\theta + r) r}_{\text{standard mechanism}}} \kappa$$

and the cutoff y^* is defined by $V^P(b, y^*(b,r), r) = V^D(\kappa)$. In this case, the risk-free rate is irrelevant for the payoffs after default. The limiting case of $\kappa = 0$ corresponds to a model in which lenders recover nothing after default and the government remains in autarky forever. This limiting case would further undermine the role of the *standard mechanism* by reducing the second term in the budget constraint from equation (11).

In the following section we present a quantitative model of sovereign default that features endogenous renegotiation in a similar fashion as above and show that, for a calibration to the Mexican default in 1982, the quantitative relevance of the *standard mechanism* is dwarfed by that of the *renegotiation mechanism*. In order to make the latter point, we use two counterfactual cases with a fixed recovery rate considering the case of no recovery $\kappa = 0$—which would be akin to the standard in the literature—and with some recovery $\kappa > 0$—which would allow the *standard mechanism* to have a larger effect.

3 Quantitative model

We now extend the above one-shot model into a quantitative sovereign default model with renegotiation. The key additions are shocks to the real interest rate and readmission to financial markets after debt renegotiation. We also allow for long-term debt and persistent income shocks. Given these assumptions, results similar to Propositions 1 and 2 cannot be proved, but, as will be clear later, the intuition behind both results persists.

Shocks and preferences.—The risk-free interest rate can take two values $r_t \in \{r_L, r_H\}$, with $r_L < r_H$, and follows a Markov chain, where π_{ij} with $j \in \{L, H\}$ are the transition probabilities. Each period, the economy receives a stochastic endowment of a tradable good y_t that follows a log-normal AR(1) process $\log(y_t) = \rho \log(y_{t-1}) + \epsilon_t$, with $|\rho| < 1$ and $\epsilon_t \sim N\left(0, \sigma_\epsilon^2\right)$. Unlike in the one-shot model, the endowment follows this stochastic process regardless of the government's financial standing. The government has preferences for consumption in each period represented by $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$ and discounts the future at a rate β.

Debt and default.—The government can issue long-term non-contingent debt in international financial markets. Similar to Hatchondo and Martinez (2009), a bond consists of a perpetuity with geometrically declining payments: a bond issued in period t promises to pay $\gamma(1-\gamma)^{j-1}$ units of the tradable good in period $t+j$, $\forall j \geq 1$. The law of motion for bonds is given by $b_{t+1} = (1-\gamma) b_t + x_t$ where b_t is the amount of bonds due at the beginning of period t, γ is the fraction of bonds that matures each period, and x_t is the issuance of new bonds. Debt is purchased by a measure 1 of identical risk-neutral competitive lenders with deep pockets who discount the future at the current risk-free rate $\frac{1}{1+r_t}$. At the beginning of each period, the government observes the realization of the shocks and b_t and decides whether to repay or default. If it chooses to default then it gets immediately excluded from financial markets. While in default, there is an asymmetric cost to output cost of the form $\phi(y_t) = \max\left\{0, \phi_0 y_t + \phi_1 y_t^2\right\}$, where $\phi_0 < 0 < \phi_1$.[6] Also, at the beginning of each period after default, an opportunity to renegotiate the outstanding debt arises with probability θ.[7]

Renegotiation.—When an opportunity to renegotiate arises, lenders and the government engage in Nash bargaining to determine a new debt level b^R for the government to re-enter financial markets with. In the renegotiation period, after b^R has been determined, the government pays γb^R and is allowed to issue new debt. Readmission with $b = b^R$ must be mutually beneficial and we continue to assume that both the government and the lenders can choose to reject an offer and delay renegotiation for a later opportunity. As in the one-shot model, a delay does not happen in equilibrium because the dead-weight cost to output in default (both in the present and future periods) implies that there is always a positive surplus to split. Unlike the one-shot model, however, the surplus is not constant, but rather dependent on both the current level of output—which determines real resources to be split—and on the level of the risk-free interest rate—which affects

[6] We take this functional form from Chatterjee and Eyigungor (2012), which implies that the cost is zero for $0 \leq y_t \leq -\frac{\phi_0}{\phi_1}$ and more than proportionally increasing for $y_t > -\frac{\phi_0}{\phi_1}$. This asymmetry allows the model to generate countercyclical spreads and default, as is observed in the data.

[7] Hatchondo, Martinez, and Sosa-Padilla (2014) consider the option to renegotiate immediately as an alternative to default. Our results would not change if we considered this option, which we exclude for simplicity.

the lenders' outside option and the value of new debt that the government could issue. Also, note that the renegotiated debt level b^R is only a function of the present and future surplus to be split, and does not depend on how much debt was defaulted on. This is an important difference between our model and the one in Hatchondo, Martinez, and Sosa-Padilla (2014). In their environment, the exchanged debt depends on outstanding debt because the outside option of the lenders is the current market value of it. This is because they model voluntary debt exchanges that happen *instead of default*, rather than *after* default. They assume that if lenders reject the exchange they can collect the current market value of the debt, while we assume that if they reject then renegotiation is delayed to a future period.

3.1 Recursive formulation

The state of the economy is (b, y, r). The value function of the government in good standing is:

$$V(b,y,r) = \max_{d\in\{0,1\}} \left\{(1-d)\,V^P(b,y,r) + dV^D(y,r)\right\} \tag{12}$$

where d is the default decision. If the government decides to repay it makes coupon payments γb and gets to issue new bonds. The value of the government in repayment is:

$$\begin{aligned} V^P(b,y,r) &= \max_{c,b'} \{u(c) + \beta\mathbb{E}[V(b',y',r')]\} \\ s.t. \quad & c + \gamma b \le y + q^P(b',y,r)[b' - (1-\gamma)b] \end{aligned} \tag{13}$$

where q^P is the price schedule of newly issued bonds. The value of the government if it chooses to default is:

$$V^D(y,r) = u(h(y)) + \beta\left\{\theta\mathbb{E}\left[V^P\left(b^R(y',r'),y',r'\right)\right] + (1-\theta)\,\mathbb{E}\left[V^D(y',r')\right]\right\} \tag{14}$$

where $h(y) = y - \phi(y)$ is the output net of default costs, and $b^R(y', r')$ is the value of renegotiated debt when the state is (y', r'). When an opportunity to renegotiate arises, b^R is determined as

$$
\begin{aligned}
& b^R(y,r) = \arg\max_{\tilde{b}} \left\{ \left[S^{LEN}(y,r) \right]^{\alpha} \left[S^{GOV}(y,r) \right]^{1-\alpha} \right\} \\
s.t. \quad & S^{LEN}(y,r) = \left[\gamma + (1-\gamma) q^P \left(b^P \left(\tilde{b}, y, r \right), y, r \right) \right] \tilde{b} - Q^D(y,r) \geq 0 \\
& S^{GOV}(y,r) = V^P \left(\tilde{b}, y, r \right) - V^D(y,r) \geq 0
\end{aligned}
\tag{15}
$$

where b^P is the policy function of the government's problem in repayment (13) and $Q^D(y,r)$ is the value of a representative lender holding delinquent bonds:

$$
\begin{aligned}
Q^D(y,r) = & \frac{\theta}{1+r} \mathbb{E} \left[\left\{ \gamma + (1-\gamma) q^P \left(b'', y', r' \right) \right\} b^R(y', r') \right] \\
& + \frac{1-\theta}{1+r} \mathbb{E} \left[Q^D(y', r') \right]
\end{aligned}
\tag{16}
$$

with $b'' = b^P \left(b^R(y', r'), y', r' \right)$. The participation constraints in (15) capture how both the government and the lenders have the option to delay renegotiation for a future period.

Note that, while the relation between the renegotiated debt b^R and the risk-free rate r is not as transparent as in the one-shot model, the same intuition laid out in the latter persists. Equation (16) shows that when the risk-free rate is high lenders discount the future at a higher rate, which directly lowers their outside option Q^D. Thus, with high r lenders are more willing to accept a lower b^R since they value immediate payments more than potentially higher future ones. The government understands that it will get better terms if renegotiation happens when the risk-free rate is high. So, if interest rates are expected to remain high (e.g. the process for r is highly persistent), then high interest rates in the present make default more attractive through expectations of better renegotiation terms (i.e. low b^R).

The price of debt in good financial standing q^P reflects the actuarially fair value of newly issued bonds b':

$$q^P(b', y, r) = \underbrace{\frac{1}{1+r}}_{\text{standard mechanism}} \mathbb{E}\left[\{1 - d(b', y', r')\}\left\{\gamma + (1-\gamma)\, q^P(b'', y', r')\right\}\right] \tag{17}$$
$$+ \underbrace{\frac{1}{1+r}}_{\text{standard mechanism}} \mathbb{E}\left[\underbrace{d(b', y', r')\frac{Q^D(y', r')}{b'}}_{\text{renegotiation mechanism}}\right]$$

where $b'' = b^P(b', y', r')$ is the government's debt issuance if it repays in the next period. Equation (17) shows how the risk-free rate affects the price of debt through both mechanisms. Through the *standard mechanism*, an increase in r lowers the market value of debt because it increases the rate at which lenders discount the future. This decreases the real amount of resources that the government can raise from a new debt issuance, which in turn makes default more attractive. Through the *renegotiation mechanism*, Q^D decreases when the interest rate is high if it is expected to remain high when an opportunity to renegotiate arrives. This further decreases q^P by making the second term in equation (17) lower.

Equilibrium.—An equilibrium is value and policy functions for the government, a price schedule q^P, a value of holding defaulted debt Q^D, and a function for renegotiated bonds b^R such that: (i) given q^P, Q^D and b^R, the value and policy functions of the government satisfy equations (12), (13) and (14); (ii) given b^R and the government's policy functions, the value Q^D satisfies the functional equation (16); (iii) given the value and policy functions of the government and given Q^D, b^R solves the bargaining problem in (15); and (iv) given the policy functions and Q^D, the price q^P satisfies equation (17).

3.2 Calibration

We consider the 1982 Mexican debt crisis, which was preceded by a sizable increase in US interest rates. We use our model to assess the extent to which this increase in US interest rates triggered the Mexican default decision and whether renegotiation dynamics played an essential role.

Table 1 presents all parameter values that we calibrate directly. Each period in the model corresponds to 1 year. The risk aversion parameter is set to a standard value, $\sigma = 2$. The AR(1) income process estimation uses HP-filtered logged Mexican GDP data from 1921 to 1983, which yields an auto-correlation parameter $\rho = 0.705$ and a standard deviation of innovations of $\sigma_\epsilon = 0.040$. We set $\gamma = 0.75$ so that the average bond duration equals 16 months, which was the average maturity of the outstanding syndicated loans Mexico had by 1982 (see Negrete Cardenas (1999)).

Table 1: Externally calibrated parameters

Parameter		Value	Details
low r	r_L	0.012	1955 - 1980
high r	r_H	0.062	1981 - 1985
Pr(low to high r)	$\pi_{L,H}$	0.01	Duration of 100 years
Pr(high to low r)	$\pi_{H,L}$	0.20	Duration of 5 years
Pr(renegotiation)	θ	0.19	5.2 years exclusion (Gelos, Sahay, and Sandleris (2011))
maturity rate	γ	0.75	Sixteen-month bonds
risk aversion	σ	2	Standard
income process	ρ	0.705	AR(1) estimation
	σ_ϵ	0.040	annual data 1933-1983

The probability of switching from the high risk-free interest rate regime to the low one is set to $\pi_{H,L} = 0.20$ so that it generates an expected duration of 5 years for the high regime. This is the time it took interest rates in the U.S. to start decreasing, as can be seen in Figure 3. Hence, implicit in our analysis is the assumption the Mexican government had the correct expectation for the duration of high world interest rates. We set the probability of switching from the low to the high risk-free interest rate regime to $\pi_{L,H} = 0.01$ so that shocks like the one we are studying are very infrequent events.

Figure 3: Real risk-free interest rate

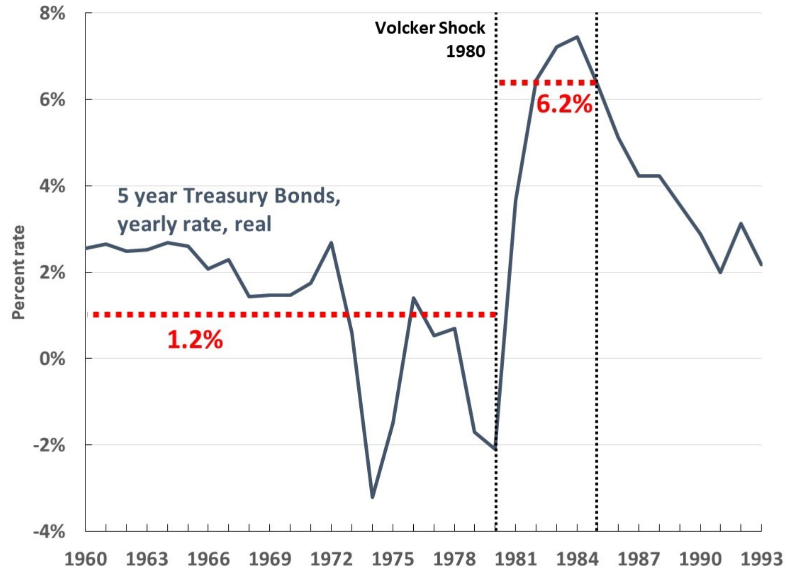


Figure 3 also displays the average interest rate during the Volcker shock (1980-1985) and the average interest rate before that (1955-1980).[8] Therefore, we set the risk-free interest rate in the low regime to $r_L = 0.012$, and to $r_H = 0.062$ in the high regime.

We set the lenders' bargaining power parameter α, the discount factor β, and the output cost parameters ϕ_0 and ϕ_1 to jointly match four moments of the Mexican economy: a haircut of 0.24 following the Brady plan, an average debt-to-GDP ratio of 0.19, a default probability of 0.03, and an average spread of 0.03.[9] The first column in Table 2 reports the parameter values for the benchmark calibration.

Table 2: Parameters chosen to match data moments

		Parameters			Targets	
		Benchmark	Full exogenous haircut	Partial exogenous haircut	from data	
Bargaining power	α	0.11			Haircut in 1990	0.24
Discount factor	β	0.82	0.77	0.89	Debt-to-GDP ratio	0.19
Quadratic income	ϕ_0	-0.20	-0.62	-0.46	Default probability	0.03
cost function	ϕ_1	0.23	0.69	0.49	Average spreads	0.03

[8] For simplicity, we assume only two possible states for the risk-free interest rate. This highlights the mechanics of the model as well as the role of the Volcker shock in triggering default episodes.

[9] Due to limited data availability, our target for the average spread considers the spreads implied in the EMBI Index for Mexico, which is available from 1997 onward. Our results are not sensitive to using the volatility of the trade balance during the relevant period as an alternative target.

In order to quantify the relevance of the *renegotiation mechanism* we consider two counterfactual cases in which the haircut to defaulted debt is determined exogenously. That is, we assume that, once a renegotiation opportunity arrives, the government is readmitted to financial markets with a debt level equal to $b^R = (1-\kappa)\,b$ where $\kappa \in [0,1]$ is the exogenous haircut. We also assume that the government can choose to reject this offer, in which case defaulted debt remains at b and the government continues to be in autarky until a new opportunity arrives. The value in default is now a function of the level of debt that the government defaulted on b:

$$V^D(b,y,r) = u(h(y)) + \beta\left\{\theta\mathbb{E}\left[V((1-\kappa)\,b,y',r')\right] + (1-\theta)\,\mathbb{E}\left[V^D(b,y',r')\right]\right\} \tag{18}$$

where the continuation value $V(b,y,r) = \max_{d\in\{0,1\}}\left\{(1-d)\,V^P(b,y,r) + dV^D(b,y,r)\right\}$ considers the government's ability to choose to remain in default. We consider two cases: the case of full exogenous haircut with $\kappa = 1$ and the case of partial exogenous haircut with $\kappa = 0.24$.[10] For each of these two cases we recalibrate the model to match the same moments as in the benchmark. The second and third columns of Table 2 report these values.

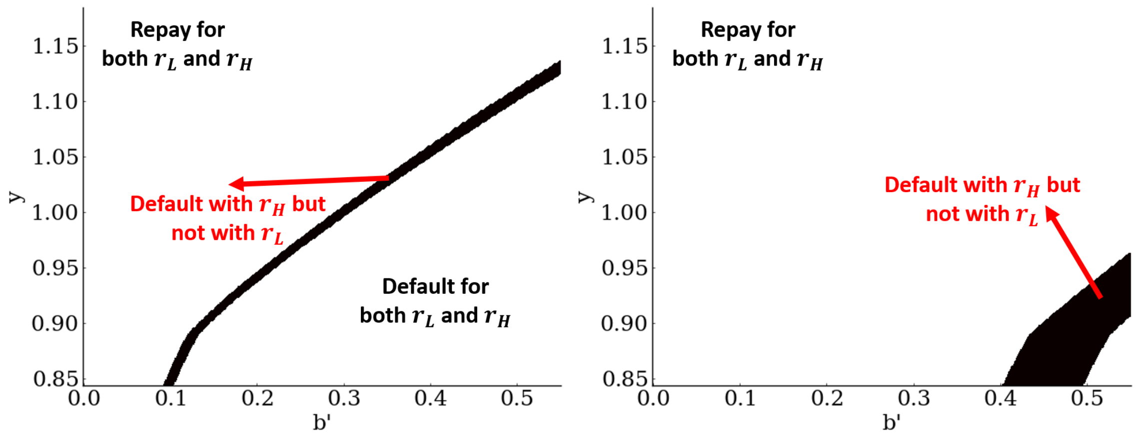
3.3 Interest rate shocks and default

In order to analyze how renegotiation affects default incentives and, more importantly, the ability of interest rate hikes to induce defaults, we divide the state space into three regions for pairs of income and debt (y,b): (i) one in which the government defaults for any risk-free interest rate, (ii) one in which it repays for any risk-free interest rate, and (iii) the region in which the government defaults only when the risk-free interest rate is high.

The left panel of Figure 4 presents these regions for the case in which there is no renegotiation and no debt recovery. This corresponds to the calibration in the second column of Table 2, which is the case where $\kappa = 1$ (or $\alpha = 0$, as discussed in footnote 10). The right panel presents these regions for the same calibration but setting $\alpha = 0.20$.

[10] Note that the case of $\kappa = 1$ is nested by the benchmark model by setting $\alpha = 0$. This gives the government all the bargaining power and allows it to make take-it-or-leave-it offers to the lenders. The lenders are still allowed to delay, in which they would wait for a future opportunity to receive a similar deal. In equilibrium, the value of any future renegotiation is erased by the government having all the bargaining power at all times, which pushes the lender's outside option to 0.

Figure 4: Default regions, effect of renegotiation



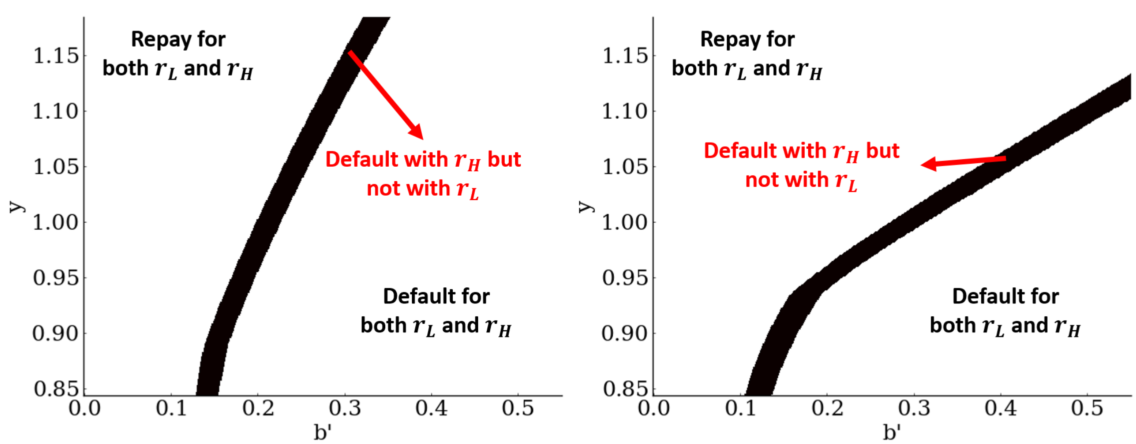
(a) No renegotiation, no recovery

(b) Renegotiation with $\alpha = 0.2$

Introducing renegotiation has two important implications in the model. First, it allows the government to sustain higher levels of debt. This is because lenders expect some positive recovery after a potential default so, for any given default probability implied by some state, the market value of debt is higher. Second, it expands the region in which default happens only with high interest rates but now with low (the black region).

Figure 5 presents the same regions for the benchmark model with renegotiation and the counterfactual case with an exogenous fixed haircut of $\kappa = 0.24$.

Figure 5: Default regions



(a) Renegotiation, benchmark

(b) Fixed exogenous haircut, $\kappa = 0.24$

Note that the black regions are thicker than their counterpart in the left panel of Figure 4. This highlights the role of renegotiation—as the comparison of both cases in Figure 4 did—but it also stresses the role of debt recovery after default, even if it is exogenous. However, note that the black region is more vertical in the case of endogenous renegotiation. This implies that, for a given level of debt, there is a larger range of income shocks that would be consistent with a default triggered solely by an interest rate hike.

The above analysis of default sets is akin to comparing policy functions of different models, which allows to understand how endogenous decisions drive simulated outcomes. We now analyze default events in the ergodic distribution of each case. For each model, we simulate 100,500 periods and drop the first 500 to avoid results being driven by initial conditions. We use these time series to compute the probability of an interest-rate hike triggering a default event, that is $\Pr(d_t = 1 | d_{t-1} = 0, r_t = r_H, r_{t-1} = r_L)$. Table 3 report this statistic for all three cases.

Table 3: Probability of interest-rate hikes triggering a default

	No renegotiation, no recovery	Fixed exogenous haircut	Endogenous renegotiation
Pr (default event|interest-rate hike)	0.06	0.13	0.22

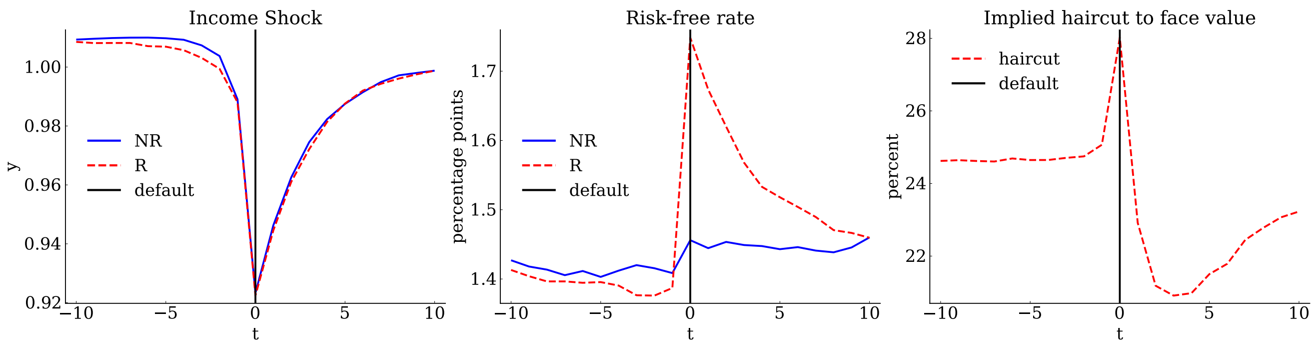
In the model with no renegotiation and no debt recovery only six percent of interest rate hikes trigger a default, while in our benchmark model this number is 22 percent. This makes the usual narrative of the 1982 Mexican default being triggered only by higher interest costs unlikely. The sole expectation of some debt recovery, even if it were independent of the interest rate, more than doubles the likelihood of interest rate shocks triggering a default (from 0.06 to 0.13). This is almost doubled again from 0.13 to 0.22 if this recovery endogenously depends on the level of the interest rate, which is our *renegotiation mechanism*.

We now compare default episodes in the benchmark model with those in the model with no debt recovery. Figure 6 displays the average paths around default episodes of income shocks, the risk-free interest rate, and a hypothetical haircut:

$$\text{haircut}_t = 1 - \frac{b^R(y_t, r_t)}{b_t} \tag{19}$$

where b^R is the renegotiation outcome defined in (15). This is the haircut that would occur if a renegotiation were to happen in period t with the shock realizations (y_t, r_t) and the defaulted debt had been b_t. We simulate 10,000 default episodes and compute the average paths in a 20-period window around each.

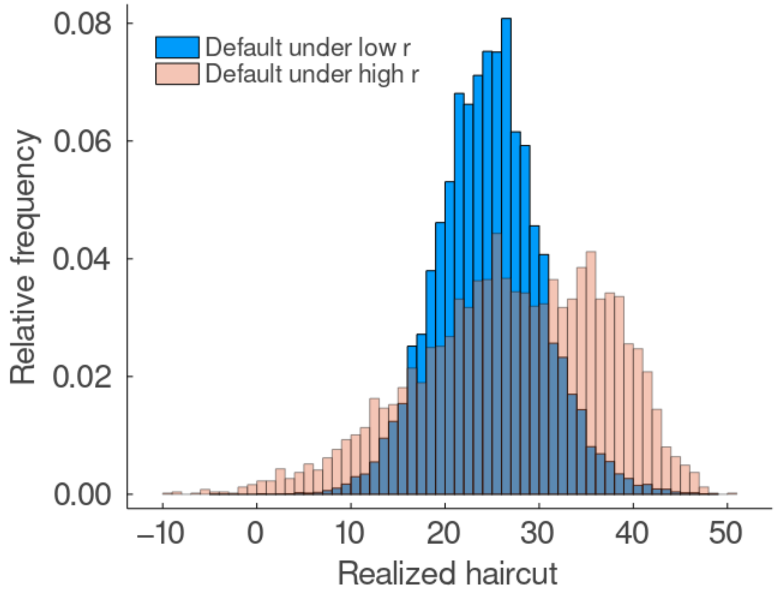
Figure 6: Paths around default events



While the pattern of income shocks is pretty similar in both models, interest-rate hikes are substantially more associated with default in the benchmark model. Also, note that the hypothetical haircut substantially increases in the periods leading up to default event, which stresses the role that better expected terms for the government play in triggering the default decision. Given the persistence of the income and risk-free interest rates, the anticipation of more favorable restructuring terms makes the default choice more attractive and borrowing more expensive. This mechanism is nonexistent in the two counterfactual models with exogenous fixed debt relief.

Figure 7 shows the distributions of realized haircuts conditional on each interest rate level. The distribution under low interest rates has a lower variance and haircuts are more concentrated around the targeted average. In contrast, the distribution under high interest rates is much more volatile and slightly skewed to the left. The higher mode and higher average of realized haircuts capture the government's improved bargaining conditions when interest rates are high.

Figure 7: Distribution of haircuts



The longer left tail with high r captures another interesting feature of the model. Governments gamble on receiving generous haircuts: their realized haircut is high in case the persistent risk-free interest rate remains high, but it is much lower if there is a regime switch. Since the default set is larger when interest rates are high, prolonged periods of high interest rates feature more renegotiation episodes involving governments with relatively low debt and high income. These are the "unlucky" cases (for the government) in the left tail of the distribution under the high regime.

3.4 Delayed renegotiation of the 1982 Mexican default

Renegotiation for Mexico took longer than the expected $\frac{1}{\theta} \approx 3.5$ years. It was only in 1989/1990 that the Brady plan resolved the 1982 default episode. A potential explanation is that US regulators did not allow banks to write down their default debt. From Lewis William Seidman, former head of the U.S. Federal Deposit Insurance Corporation, in Seidman (2000):

"*Had these institutions been required to mark their sometimes substantial holdings of under-water debt to market or to increase loan-loss reserves to levels close to the expected losses on this debt (as measured by secondary market prices), then institutions such as Manufacturers Hanover, Bank of America, and perhaps Citicorp would have been insolvent.*"

It was not only US monetary policy but also banking regulatory decisions that have a bearing on the 1980s debt crisis. Loans to a single borrower could not exceed 10 percent of bank's capital; nevertheless, different government agencies in foreign countries were considered different borrowers. During the 1980s, banks were exempted from building reserves for delinquent least developed countries' loans. Seidman (2000) claims that there were non-profit maximizing incentives for lending during the 1980s which we do not model in this paper:

"*The entire Ford administration, including me, told the large banks that the process of recycling petrodollars to the less developed countries was beneficial, and perhaps a patriotic duty.*"

4 Evidence

We use the dataset constructed by Asonuma, Niepelt, and Ranciere (2023), who compute haircut measures for different sovereign debt instruments in various restructuring episodes. Following Sturzenegger and Zettelmeyer (2008), the haircut for a debt instrument i exchanged for another instrument e (herafter SZ-haircut) is:

$$h_{i,e}^{SZ} = 1 - \frac{NPV(r_e, x_e)}{NPV(r_e, x_i)} \tag{20}$$

where $NPV(r,x)$ is the net present value of the cash flow stream of a debt instrument discounted at a rate r and x is a vector of characteristics of the instrument such as its face value, maturity, and coupon structure. A key detail is that both streams are discounted at the exit yield of the new instrument r_e, which reflects the creditor's new repayment capacity moving forward. Thus, the haircut defined in (20) captures the actual loss to investors of the new characteristics x_e relative to a benchmark with the old characteristics x_i under the new economic conditions captured by r_e.[11]

The data of SZ-haircuts from Asonuma, Niepelt, and Ranciere (2023) is for 531 instruments from 44 restructurings. We focus strictly on restructurings that happen after default, as the ones in our model, which restricts our sample to 139 instruments in 17 episodes. For each instrument, pre- and post- exchange, they report exit yields r_e and compute $NPV(r_e, x)$ considering changes to the face value, as well as to the maturity and coupon structure. The key variables that we focus on are:

[11] Sturzenegger and Zettelmeyer (2008) interpret this benchmark as the "value of free-riding", which is what an investor would get by unilaterally keeping the old instrument but taking advantage of the creditor's new paying capacity.

exit yields, net present values of old and new instruments, indicators for whether the restructuring happened pre or post default, the remaining maturity of the exchanged instruments at the time of the exchange, fixed coupon rates, and an indicator for floating coupon rates.

In the remainder of this section we present evidence of the main result of the paper: haircuts are larger when risk-free interest rates are high.

4.1 SZ-haircuts

In this subsection We estimate the following random effects regression:

$$h^{SZ}_{i,e,j,t} = \alpha + \beta r_t + \Gamma Z_{i,e} + u_j + \epsilon_{i,e,j,t} \tag{21}$$

where $h^{SZ}_{i,e,j,t}$ is the SZ-haircut to instrument i exchanged for instrument e during episode j at date t, r_t is the 1-year US real interest rate at date t (we use monthly values since the data include the exact date of the exchange), u_j is the random effect for episode j, $\epsilon_{i,e,j,t}$ is the error term, and $Z_{i,e}$ is a vector of relevant controls considered by Asonuma, Niepelt, and Ranciere (2023): the remaining time to maturity at the time of the exchange, the coupon rate of e if it is fixed, and an indicator variable of whether e has a floating coupon rate. Table (4) presents the regression results.

Table 4: Regression results with SZ-haircuts

	Without controls	With controls		
	(1)	(2)	(3)	(4)
real risk-free rate	7.030**	7.015**	6.510*	6.329*
	(2.951)	(3.039)	(3.609)	(3.800)
maturity of instrument (years)		0.0960	-0.232**	-0.225**
		(0.0813)	(0.106)	(0.107)
coupon rate (fixed, percent)			0.939***	1.091***
			(0.168)	(0.377)
coupon rate (float, dummy)				1.914
				(4.254)
constant	37.06***	36.53***	36.36***	35.29***
	(5.196)	(5.367)	(6.284)	(6.965)
Observations	139	139	78	78
Number of episodes	17	17	14	14
Episode random effects	Yes	Yes	Yes	Yes

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The main result is that the coefficient β on the real risk-free rate is positive and significantly different from 0. Each additional percentage point in risk-free rates increases haircuts by between 6 and 7 percentage points. This result is robust to controling for other relevant variables studied by Asonuma, Niepelt, and Ranciere (2023). It is worth mentioning that their main result remains unchanged: haircuts are lower for longer maturity bonds.

4.2 Model haircuts

An important difference between the model and the data is that haircuts in the data consider changes to the face value of the debt, its maturity, and its coupon structure; while in the model only the face value b is renegotiated and the maturity rate γ is fixed. In this subsection we compute, for each haircut observed in the data, its model equivalent that considers our simplifying assumptions and benchmark calibration. The positive relationship between risk-free rates and our data measure of model haircuts continues to hold.

Consider an instrument i with face value b_i. Let $\gamma_{i,t}$ be its maturity rate in period t and $\kappa_{i,t}$ its coupon rate. In the data, the net present value of the cash flow from i discounted at the exit rate r_e is:

$$NPV^d\left(r_e, x_i^d\right) = \sum_{t=0}^{\infty}\left(\frac{1}{1+r_e}\right)^t\left[\prod_{s=0}^{t}\left(1-\gamma_{i,s}\right)\right]\left[\gamma_{i,t}+\kappa_{i,t}\left(1-\gamma_{i,t}\right)\right]b_i \tag{22}$$

where $x_i^d = \left(b_i, \gamma_{i,0}, \gamma_{i,1}, \ldots, \kappa_{i,0}, \kappa_{i,1}, \ldots\right)$. In the model, γ is a fixed parameter and $\kappa = 0$, so the analogous expression is

$$NPV^m\left(r_e, x_i^m\right) = \sum_{t=0}^{\infty}\left(\frac{1-\gamma}{1+r_e}\right)^t \gamma b_i = \gamma b_i \frac{1+r_e}{\gamma+r_e} \tag{23}$$

where $x_i^m = \left(b_i, \gamma\right)$. When debt is renegotiated in the model, for a given income and risk-free rate (y, r), the net present value of the cash flow stream of renegotiated debt b^R is:

$$NPV^m\left(r_e, \left(b^R, \gamma\right)\right) = \gamma b^R + q^R\left(1-\gamma\right)b^R = \gamma b^R \frac{1+r^e}{\gamma+r^e} \tag{24}$$

where $q^R = q\left(b^P\left(b^R\left(y,r\right), y, r\right)\right)$ and r^e is an exit yield that makes the second equality hold. Thus, the SZ-haircut in the model is

$$h^{SZM} = 1 - \frac{\gamma b^R \frac{1+r^e}{\gamma+r^e}}{\gamma b \frac{1+r^e}{\gamma+r^e}} = 1 - \frac{b^R}{b} \tag{25}$$

which is simplified significantly by the fact that both streams are discounted by the same r^e and that the maturity rate remains unchanged. In the data, the losses incurred by lenders come from changes to maturity and coupon structures, as well as changes to the face value of the debt. In the model, all loses are captured by the change from b to b^R.

Given data for r_e for each restructured instrument and given our calibrated value $\gamma = 0.75$, we compute, for each observed $NPV^d\left(r_e, x_i^d\right)$, a model face value b_i by combining equations (22) and (23):

$$NPV^d\left(r_e, x_i^d\right) = \gamma b_i \frac{1+r_e}{\gamma+r_e}$$

which is the face value that would generate the same $NPV^d\left(r_e, x_i^d\right)$ if the instrument had the model's maturity and coupon structures and the future risk captured by r_e remained unchanged. We use these face values to calculate model-haircuts $h_{i,ej,t}^{SZM}$, following equation (25), for each instrument i exchanged for instrument e during episode j in period t. Table (5) presents the estimation of equation (21) using as a dependent variable these haircuts.

Table 5: Regression results with model haircuts

	Without controls		With controls	
	(1)	(2)	(3)	(4)
real risk-free rate	7.602**	7.535**	7.117*	6.807*
	(3.484)	(3.592)	(3.746)	(3.966)
maturity of instrument (years)		0.101	-0.232**	-0.222**
		(0.0997)	(0.106)	(0.107)
coupon rate (fixed, percent)			0.956***	1.226***
			(0.171)	(0.410)
coupon rate (float, dummy)				3.292
				(4.554)
constant	35.48***	34.82***	34.81***	32.96***
	(6.051)	(6.268)	(6.683)	(7.468)
Observations	94	94	75	75
Number of episodes	14	14	13	13
Episode random effects	Yes	Yes	Yes	Yes

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

The main result continues to hold. The estimated effect of risk-free rates on our measure of model haircuts is slightly stronger, with a magnitude between 6.8 and 7.6 percentage points.

5 Conclusion

We developed a theory of sovereign default and debt renegotiation in which shocks to risk-free interest rates affect default incentives through two mechanisms. The first is the *standard mechanism* through which higher interest rates directly tighten the budget constraint of the borrowing government. The second, which we labeled the *renegotiation mechanism*, rests on how risk-free interest rates affect the opportunity cost to lenders of holding delinquent debt. When interest rates are high, this cost increases and lenders are more willing to accept larger haircuts on defaulted government debt. Governments in good standing understand this and find default more attractive when they expect high interest rates to persist. Quantitatively, this novel mechanism is more relevant than the standard one alone and we find that it is crucial to reconcile the widespread narrative that the Volcker interest-rate hikes caused the 1982 Mexican default.

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A Proofs

Lemma 1. If $\alpha \in (0,1)$, then there is a unique $\rho^* \in (0,1)$ that solves the bargaining problem in (4).

Proof: The first-order-condition of the bargaining problem implies

$$\alpha \left[\frac{u(1-\rho^*) - u(\lambda)}{1-\beta(1-\theta)} \right] = \frac{(1-\alpha)\, r}{\theta + r} \frac{u'(1-\rho^*)}{1-\beta} \rho^*$$

where u is strictly increasing and concave. Note that when $\rho^* \to 0$ the left-hand-side is positive, while the right-hand-side is zero. Similarly, when $\rho^* \to 1$ the left-hand-side is negative, while the right-hand-side is positive. Since u and u' are continuous, then the Intermediate Value Theorem implies the existence of a solution ρ^*. Moreover, since both sides of the equation are monotonic then the solution is unique.□