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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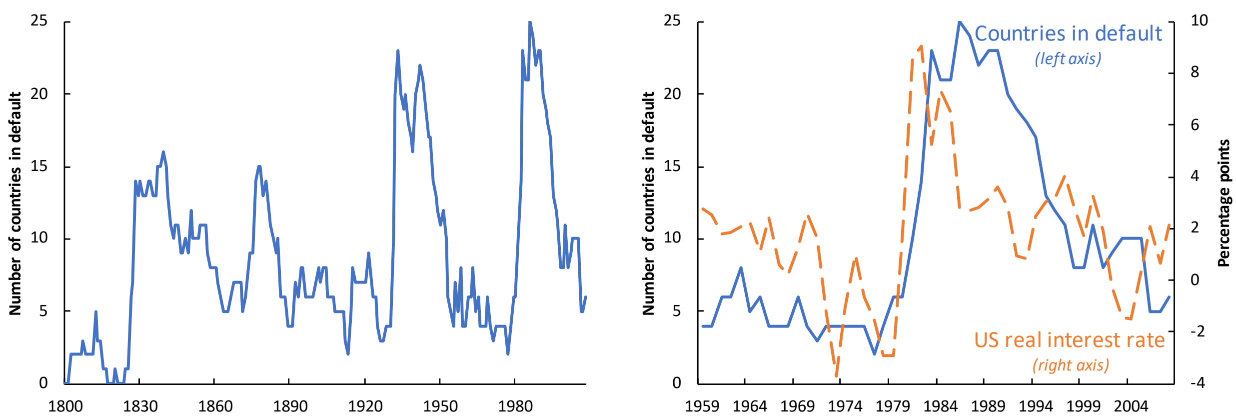
1 Introduction

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.

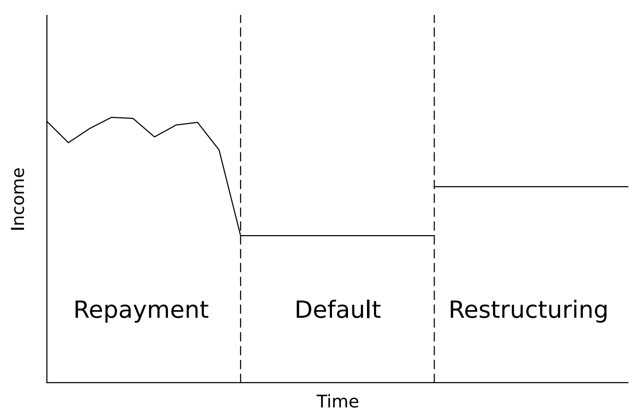
Layout.—Section 2 presents a "one-shot" model of sovereign default and renegotiation which highlights the intuition behind our main result. Section 3 presents the general model and the quantitative exercises. Section 6 concludes.

2 A simple standard model

In this section we solve a simple model of sovereign default. The main innovation is to explicitly model the renegotiation game following default. The purpose is to characterize the properties of the renegotiation mechanism that is at the heart of the paper.

An impatient government faces a stochastic stream of income and issues short-term defaultable debt. Every period the government can decide to default or repay. In case of default, the government is in financial autarky for a stochastic number of periods and suffers an income loss during exclusion. Income is fixed at a value lower than its average and there are no payments made to the lenders. During exclusion, the government and the lenders face a positive probability of renegotiation. Upon a successful renegotiation the government receives a constant flow of income, higher than the value during exclusion, and pays a fixed coupon to lenders forever. Figure 2 illustrates the evolution of income over time throughout the game.

Figure 2: Income throughout the game



These assumptions imply that eventually, after renegotiation, the allocation is stationary and easy to solve. This allows us to solve for the equilibrium by backwards induction and obtain some enlightening results.

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 determines 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

$$\mathbb{E}_t\left[\sum_{s=t}^{\infty}\beta^{s-t}u\left(c_s\right)\right]$$

where $\beta \in (0,1)$ is a discount factor, and u is continuously differentiable, strictly increasing, and strictly concave. 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 bonds b_{t+1} that pay one unit of the good in $t+1$ in case of no default. Debt is purchased by a measure 1 of identical risk-neutral lenders with deep pockets who also have access to a risk-free bond that pays a fixed interest rate r. In the full model in the next Section r varies stochastically to reproduce the Volcker shock. In this Section we treat r as a parameter, and we show our results by performing simple comparative statics for different values of r. Therefore, we express all equilibrium objects as functions of this parameter 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 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 an agreement is reached. After renegotiation, the government receives a constant stream of income equal to 1 forever, out of which it consumes $1-\rho > 0$ in each period. The value $\rho > 0$ is captured by the lenders (that is, 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. The opportunities to renegotiate arrive with probability θ.

As it turns out, agreements in equilibrium are reached at the first possibility of renegotiation, because $\lambda < 1$ implies that there is a strictly positive surplus that can be split. As we will show, however, it is the possibility of rejecting and waiting that allows the interest rate to have an important role in the determination of the equilibrium value of the outcome of the renegotiation game ρ^*.

To define and characterize the equilibrium we proceed backwards by characterizing the outcome of the renegotiation game ρ^* guessing and then verifying that it is unique. We then use this characterization to define the equilibrium of the model.

Renegotiation.—Given some renegotiation outcome 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 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 when the renegotiation outcome is ρ 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 for the lenders of receiving ρ every period once the renegotiation game is settled. Guessing that the equilibrium outcome will be the same value ρ—regardless of the timing of its resolution—we plug Q^A into equation (2) and 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 government engage in Nash bargaining. We define the outcome $\rho^*(r)$ as

$$\begin{aligned} \rho^*(r) &= \arg\max_{\tilde{\rho}} \left[S^{LEN}(\tilde{\rho})\right]^{\alpha}\left[S^{GOV}(\tilde{\rho})\right]^{1-\alpha} \\ s.t. \quad S^{GOV}(\tilde{\rho}) &= V^A(\tilde{\rho}) - V^D(\rho^*(r)) \geq 0 \\ S^{LEN}(\tilde{\rho}) &= Q^A(\tilde{\rho}) - Q^D(\rho^*(r)) \geq 0 \end{aligned} \tag{4}$$

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 of waiting for a future renegotiation with outcome $\rho^*(r)$. Assuming an interior solution, the first-order condition of the problem in (4) is

$$\alpha\left[\frac{u(1-\rho^*(r)) - u(\lambda)}{1-\beta(1-\theta)}\right] - \frac{(1-\alpha)r}{\theta+r}\frac{u'(1-\rho^*(r))}{1-\beta}\rho^*(r) = 0 \tag{5}$$

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

Proposition 1. There is a unique $\rho^* \in [0,1]$ that solves the bargaining problem in (4) which is decreasing in r.

Proof: The left-hand-side of equation (5) is positive for $\rho^* = 0$ (since u is increasing and concave) and becomes negative as $\rho^* \to 1$. By the Intermediate Value Theorem, there is a $\rho^* \in [0,1]$ that satisfies equation (5). In addition, since u and u' are monotonic, this solution ρ^* is unique.

If $\alpha = 1$ then $\rho^*(r) = 1-\lambda$ and if $\alpha = 0$ then $\rho^*(r) = 0$, regardless of the value of r. For any $\alpha \in (0,1)$ we can rearranging equation (5) to get

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

where the left-hand-side is decreasing in $\rho^*(r)$ (this follows from u being increasing and concave) and the right-hand-side is strictly increasing in r. If the interest rate increases then the right-hand-side increases, so $\rho^*(r)$ must decrease for the left-hand-side to increase for the equality to hold. This implies that the unique renegotiation outcome ρ^* is decreasing in the parameter r. $\square$

For r to have an impact on the renegotiation outcome it is crucial that both parties have something to gain from the renegotiation game. The fact that both parties have the possibility to choose to delay the renegotiation process implies that both get a positive value out of the game.

Recursive formulation.—Given the above characterization of the renegotiation game, the value of the government in good financial standing is

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

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

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

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 $\mathcal{D}(b;r) = \left\{ y \in (0,2) \,|\, V^P(b,y;r) < V^D(\rho^*(r);r) \right\}$ is characterized by a cutoff value $y^*(b;r)$ such that

$$V^P(b, y^*(b;r); r) = V^D(\rho^*(r)). \tag{8}$$

Equilibrium.—An equilibrium is value functions V, V^P and V^D, 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:

$$q(b';r) = \frac{1 - F(y^*(b';r))}{1+r} + \frac{F(y^*(b';r))}{1+r}\frac{Q^D(\rho^*(r))}{b'} \tag{9}$$

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

2.1 Renegotiation matters

The risk-free rate r affects default incentives 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 the future (i.e. the denominators in the pricing equation (9)). This direct effect reduces $q(b';r)$ in (3), tightening the government's budget constraint.

The second, which we call the *renegotiation mechanism*, refers to how r affects the renegotiation outcome ρ^* and, through it, how it shifts the price schedule q and the value of defaulting V^D. Equation (3) shows that a larger interest rate reduces the lenders' outside option in the bargaining game because their opportunity cost of delaying collection of payments increases. This makes them willing to accept a lower value for ρ^* and, in turn, reduces the ex-ante value of its debt q through the second term in the pricing equation (9). Thus, this better outcome increases both the value of default through a higher value after renegotiation, and reduces the value of repayment through a tighter budget constraint.

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 is increasing in r. Also, it is clear from equation (7) that

V^P is decreasing in r. Then, for equation (8) 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 fixed $\rho^* = \kappa \in (0,1)$. The value of repayment in equilibrium becomes

$$V^P(b,y;r,\kappa) = \max_{b'} \{u(c) + \beta \mathbb{E}[V(b',y';r,\kappa)]\} \tag{10}$$
$$s.t. \quad c + b \leq y + \frac{1 - F(y^*(b';r,\kappa))}{1+r} b' + \frac{\theta F(y^*(b';r,\kappa))}{(\theta + r) r} \kappa$$

and the cutoff y^* is now defined by

$$V^P(b, y^*(b;r,\kappa); r,\kappa) = V^D(\kappa).$$

The risk-free rate is irrelevant for the payoffs after default in this case. The limit $\kappa \rightarrow 0$ 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 eliminating the second term in the budget constraint from equation (10).

In a sense, our previous assumptions make the above model almost static. In the next Section we augment a state-of-the-art sovereign default model to include the renegotiation mechanism that we highlight in this Section.

We calibrate this state-of-the-art model to Mexico in the early 1980s, and we show that the quantitative significance of the *renegotiation mechanism,* coupled with the *standard mechanism,* is far larger than that of the *standard mechanism* by itself.

3 Quantitative model

We now extend our simple 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 simple 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 issues 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 $1/(1+r_t)$. 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, we follow Chatterjee and Eyigungor (2012) and assume the following asymmetric cost to output

$$\phi(y_t) = \max\left\{0, \phi_0 y_t + \phi_1 y_t^2\right\}, \text{ where } \phi_0 < 0 < \phi_1.$$

At the beginning of each period after default, an opportunity to renegotiate the outstanding debt arises with probability θ.

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 have the option to reject an offer and delay renegotiation for a later opportunity. As in the simple 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 simple 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 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.

Our bargaining game endogenously determines a haircut. Consequently, we do not impose an exogenous haircut—as is customary in the literature. This raises the question of what is the appropriate benchmark to which we should compare our model. We consider the two obvious alternatives. First, we compare our results to those from a model in which the haircut is 100 percent. Second, we consider a model with a fixed haircut calibrated to the observed haircut for Mexico, as is standard.[5] An attractive feature of this case is that we calibrate the bargaining power of the country in the model with the renegotiation mechanism to also match the same average haircut. Thus, by comparing these two cases we can disentangle the effect of the endogenous haircut mechanism.

[5] We thank Francisco Roch for suggesting this alternative benchmark.

3.1 Recursive formulation

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

$$V(b, y, r) = \max_{d \in \{0,1\}} \left\{ (1-d) V^P(b, y, r) + d V^D(y, r) \right\} \tag{11}$$

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:

$$\begin{aligned} V^P(b, y, r) &= \max_{c, b'} \{ u(c) + \beta \mathbb{E}[V(b', y', r')] \} \\ s.t. \quad c + \gamma b &\leq y + q^P(b', y, r)[b' - (1-\gamma) b] \end{aligned} \tag{12}$$

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

$$V^D(y, r) = u(h(y)) + \beta \left\{ \theta \mathbb{E}\left[V^P\left(b^R(y', r'), y', r' \right) \right] + (1-\theta) \mathbb{E}\left[V^D(y', r') \right] \right\} \tag{13}$$

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

$$\begin{aligned} b^R(y, r) &= \arg\max_{\tilde{b}} \left\{ \left[S^{LEN}(y, r) \right]^{\alpha} \left[S^{GOV}(y, r) \right]^{1-\alpha} \right\} \\ s.t. \quad S^{LEN}(y, r) &= \left[\gamma + (1-\gamma) q^P\left(b^P(\tilde{b}, y, r), y, r \right) \right] \tilde{b} - Q^D(y, r) \geq 0 \\ S^{GOV}(y, r) &= V^P(\tilde{b}, y, r) - V^D(y, r) \geq 0 \end{aligned} \tag{14}$$

where b^P is the policy function of the government's problem in repayment (12) and $Q^D(y, r)$ is the value of a representative lender holding defaulted bonds:

$$\begin{aligned} Q^D(y, r) = & \frac{\theta}{1+r} \mathbb{E}\left[\left\{ \gamma + (1-\gamma) q^P(b'', y', r') \right\} b^R(y', r') \right] \\ & + \frac{1-\theta}{1+r} \mathbb{E}\left[Q^D(y', r') \right] \end{aligned} \tag{15}$$

with $b'' = b^P\left(b^R(y',r'),y',r'\right)$. The participation constraints in (14) capture how both the government and the lenders have the option to delay renegotiation for a future period.

The relation between the renegotiated debt b^R and the risk-free rate r is not as transparent as in the simple model, but the same intuition laid out in the latter persists. Equation (15) 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':

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

where $b'' = b^P(b',y',r')$ is the government's debt issuance if it repays in the next period.

Equation (16) 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 (16) lower. If the recovery value was exogenously fixed this last effect would vanish. A higher r would still make default more attractive but only through its direct effect on the government's budget constraint due to q^P shifting downward. Moreover, this shift would be only driven by the *standard mechanism* since Q^D in the right-hand-side of equation (16) would be invariant to r.

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 (11), (12) and (13); (ii) given b^R and the government's policy functions, the value Q^D satisfies the functional equation (15); (iii) given the value and policy functions of the government and given Q^D, b^R solves the bargaining problem in (14); and (iv) given the policy functions and Q^D, the price q^P satisfies equation (16).

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

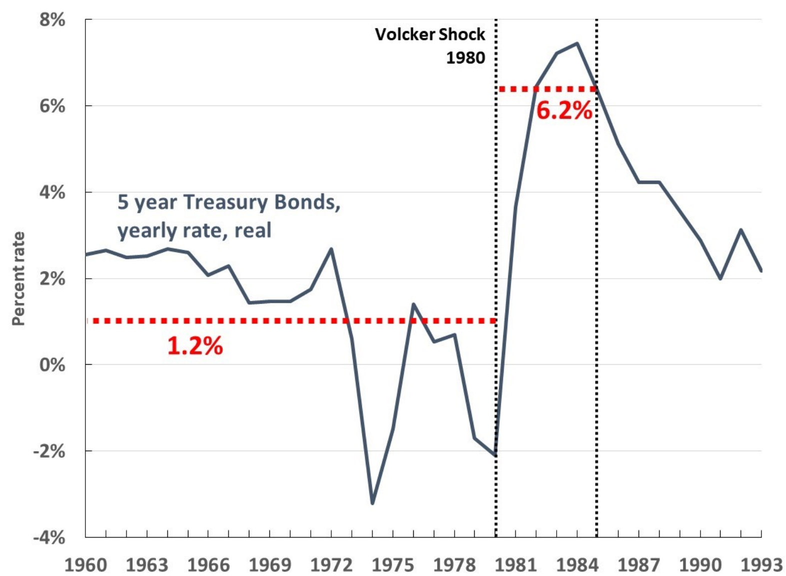


Figure 3 also displays the average interest rate during the Volcker shock (1980–1985) and the average interest rate before that (1955–1980).[6] Therefore, we set the risk-free interest rate in the low regime to $r_L = 0.012$, and to $r_H = 0.062$ in the high regime.

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.[7] The first column in Table 2 reports the parameter values for the benchmark calibration.

[6]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.

[7]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.

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

To quantify the relevance of the *renegotiation mechanism* we consider two alternative economies 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:

$$V_\kappa^D(b,y,r) = u(h(y)) + \beta\left\{\theta\mathbb{E}\left[V_\kappa((1-\kappa)\,b,y',r')\right] + (1-\theta)\,\mathbb{E}\left[V_\kappa^D(b,y',r')\right]\right\} \tag{17}$$

where the continuation value

$$V_\kappa(b,y,r) = \max_{d\in\{0,1\}}\left\{(1-d)\,V_\kappa^P(b,y,r) + dV_\kappa^D(b,y,r)\right\}$$

considers the government's ability to choose to remain in default and V_κ^P and all other objects are defined as before. We consider two cases: the case of full exogenous haircut with $\kappa = 1$ and the case of partial exogenous haircut with $\kappa = 0.24$, the relevant value for Mexico.[8] 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.

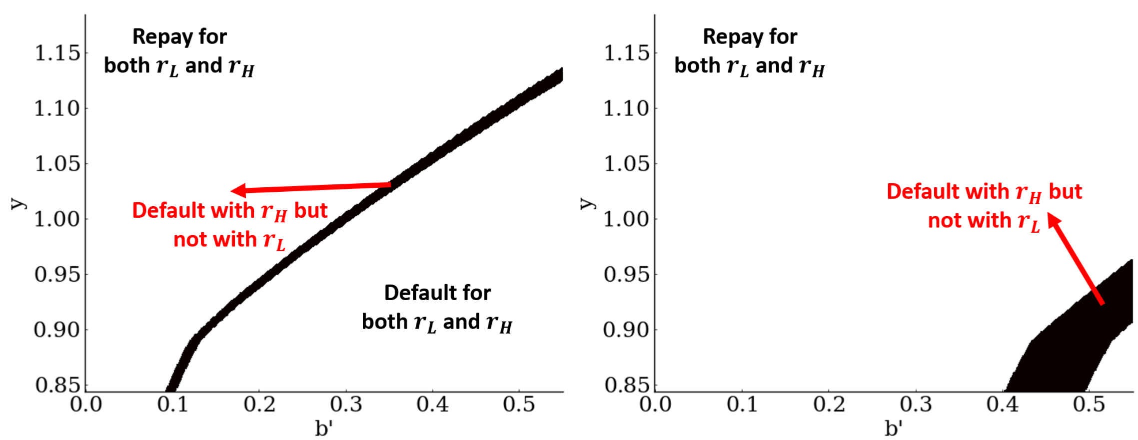
[8]Note that the case of $\kappa = 1$ is nested by the benchmark model by setting $\alpha = 0$. This gives the government all the bargaining power and allows it to make take-it-or-leave-it offers to the lenders. The lenders are still allowed to delay, in which they would wait for a future opportunity 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.

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 8). The right panel presents these regions for the same calibration but setting $\alpha = 0.20$.

Figure 4: Default regions, effect of renegotiation



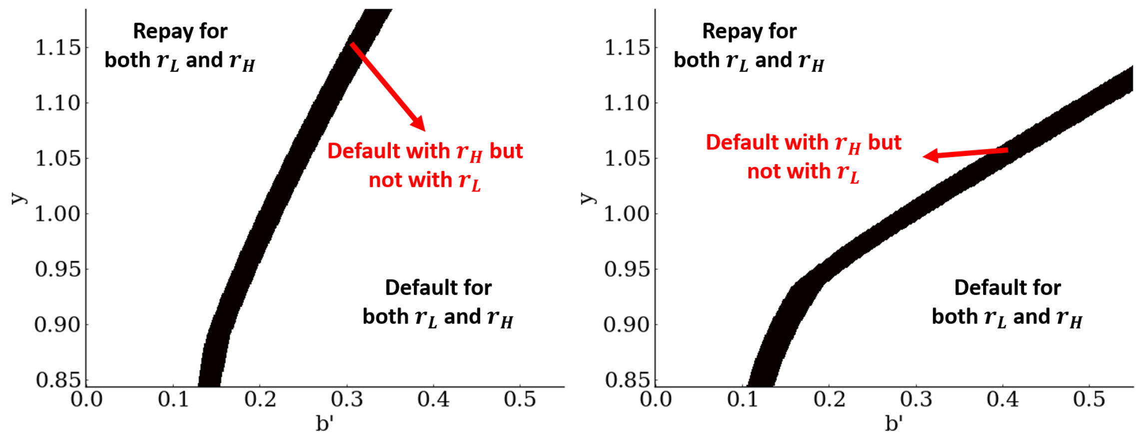
(a) No renegotiation, no recovery

(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	0.24

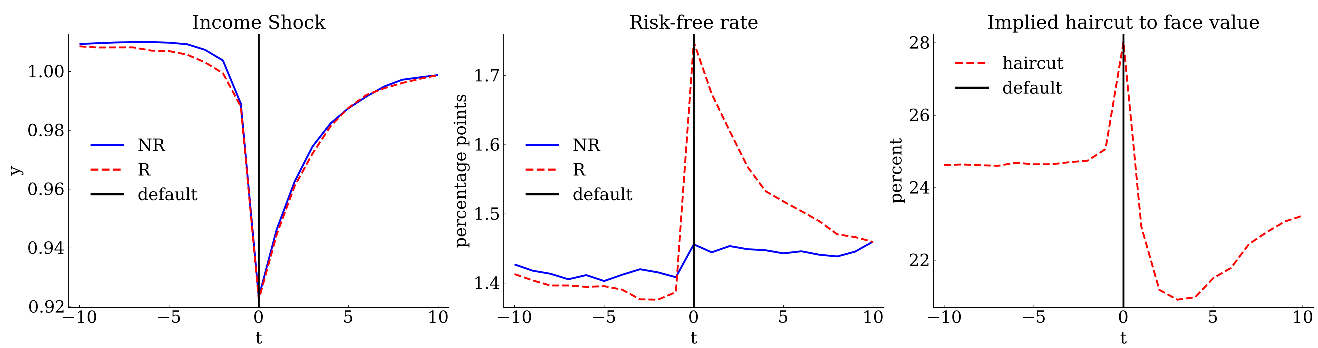
In the model with no renegotiation and no debt recovery only six percent of interest rate hikes trigger a default, while in our benchmark model this number is 22 percent. This makes the usual narrative of the 1982 Mexican default being triggered only by higher interest costs unlikely. The sole expectation 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:

$$\text{haircut}_t = 1 - \frac{b^R\left(y_t, r_t\right)}{b_t} \tag{18}$$

where b^R is the renegotiation outcome defined in (14). 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.

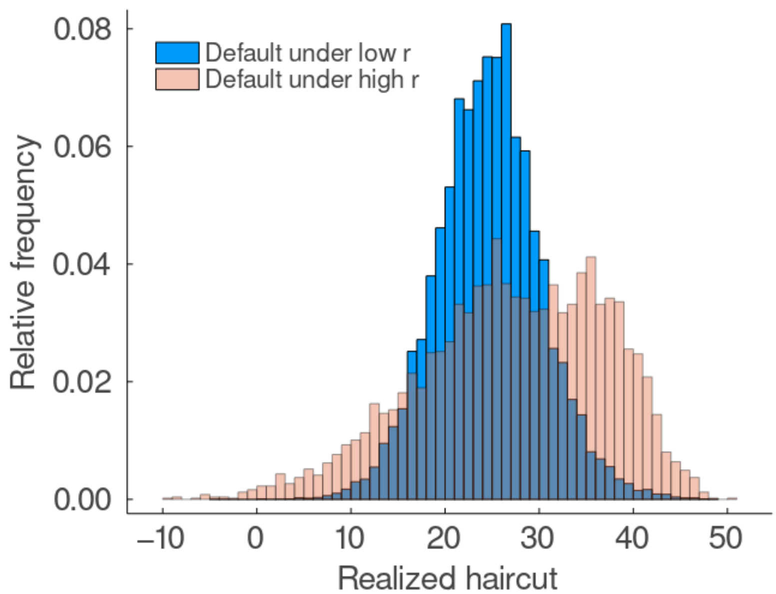
Figure 6: Paths around default events



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.

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:

$$h_{i,e}^{SZ} = 1 - \frac{NPV(r_e, x_e)}{NPV(r_e, x_i)} \tag{19}$$

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 (19) 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.[9]

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.

Our Nash bargaining procedure abstracts from common features of renegotiation outcomes, such as changes to maturity and coupon structure. In Appendix A, we describe how we use this dataset to compute a model equivalent measure of haircuts that considers our simplifying assumptions.

We estimate the following random effects regression:

$$h_{i,e,j,t}^{SZ} = \alpha + \beta r_t + \Gamma C_{i,e} + u_j + \epsilon_{i,e,j,t} \tag{20}$$

where $h_{i,e,j,t}^{SZ}$ 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 $C_{i,e}$ 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 instrument e if it is fixed, and an indicator variable on whether e has a floating coupon rate.

[9] 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.

Table (4) presents our main empirical result: the coefficient on the real risk-free interest rate is positive and significantly different from 0, which indicates that haircuts are larger when risk-free interest rates are higher. Columns (1) and (2) report the estimation of equation 20 with and without controls. Each additional percentage point in risk-free rates increases haircuts by between 6 and 7 percentage points.

Table 4: Regression results

	SZ-haircuts		Model haircuts	
	(1)	(2)	(3)	(4)
real risk-free rate	7.030**	6.329*	7.602**	6.807*
	(2.951)	(3.800)	(3.484)	(3.966)
maturity of instrument (years)		-0.225**		-0.222**
		(0.107)		(0.107)
coupon rate (fixed, percent)		1.091***		1.226***
		(0.377)		(0.410)
coupon rate (float, dummy)		1.914		3.292
		(4.254)		(4.554)
constant	37.06***	35.29***	35.48***	32.96***
	(5.196)	(6.965)	(6.051)	(7.468)
Observations	139	78	94	75
Number of episodes	17	14	14	13
Episode random effects	Yes	Yes	Yes	Yes

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

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. We compute, for each haircut observed in the data, its model equivalent that considers our simplifying assumptions and benchmark calibration. The details of our calculations are in Appendix 7.

Columns (3) and (4) in Table (4) show that the positive relationship between risk-free rates and our data measure of model haircuts 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. This result is robust to controling for other relevant variables studied by Asonuma, Niepelt, and Ranciere (2023) (Appendix B provides additional robustness analyses). Table (4) supports our proposed mechanism that governments predict more favorable debt relief when risk-free interest rates increase.

5 The 1980s lost decade

In our calibration, we followed standard practice in the literature in that we used historical data, including the debt default episodes of the 80s to discipline the parameters. As the contribution of the paper is to show how explicitly considering the post default re-negotiation game—particularly when the parameters of the re-negotiation are treated as endogenous outcomes—substantially changes the magnitude of temporary increases in the international risk free rate, this was the natural choice. The increase in the real rate in the early 80s is the natural laboratory to study shocks to the risk free rate. Viewed this way, the case of Mexico in 1982 is one of many we could use.

However, in interpreting the events of Mexico in particular, and of many other Latin-American countries in general, there is some tension between the interpretation of the paper and the real outcomes. Indeed, the interpretation of the paper is that, to some extent, the "Volcker shock" had a direct, negative impact on Mexico—and all other indebted countries in the region. But, on the other hand, by making the lenders face a higher discount factor, their eagerness to reach a fast re-negotiation would translate into a relatively fast renegotiation with better terms for these countries. This is strongly at odds with the narrative of the "Lost Decade" for Mexico and other Latin-American countries.

Of course, our model is not inconsistent with the narrative. A possible interpretation, within the real of our quantitative model, is that even though the renegotiation probability was relatively high, Mexico—and all other Latin-American countries—had bad luck, and it took about a decade on average for these countries to actually face a renegotiation opportunity. Meanwhile, these countries faced the default cost that implied a lost decade.

While consistent with the model, this interpretation does not survive the test of history. In this Section we briefly review the events that unravelled following Mexico's default, in particular, the role played by US government officers and regulators in the episode. In doing so, we argue, the parameter we used for the probability of having a re-negotiation opportunity, is not the one that was relevant for Mexico in 1982.

In a nutshell, the argument goes as follows: In defaulting Mexico was expecting to be able to reach an agreement with its creditor relatively soon. After Mexico defaulted, several other countries followed. In fact, within six months after the default they started their attempts to renegotiate with the Banks. However, due to lack of prudent behavior on the side of banks, the losses generated by the default episodes, was, in some cases, almost as large as the capital of the Banks. This create concerns among US regulators that a failure of some of the Banks could create a Bank panic similar to the one experienced during the Great Depression of the 30s. The "too big to fail" doctrine took stage, and US regulators intervened, by not allowing the Banks to write of some of their losses until it would be safe to do. At the same time, the Banks saw an opportunity to be bailed out by the US government, a process for which some evidence exists - see Dooley's quotes below. The resolution of the default episodes if the 80s was the outcome of a game much more complicated than the standard sovereign debt model that we solved: it involved the sovereign, the lenders and the US regulators. Both the Banks and the US regulators saw benefits in delaying the renegotiation, a factor that was not necessarily in the cards when Mexico decided to default in the summer of 1982.

In our benchmark calibration, following standard practice, we assumed the probability of having a renegotiation opportunity to be about 1 every 5 years. Relative to the specific experience of Mexico, this number appears too low, since it took almost a decade for the Brady plan to resolved the Mexican 1982 default episode. In what follows, we argue exactly the opposite: a natural assumption for Mexico in August of 1982 was that the perceived probability of a renegotiation was substantially higher than 1 every 5 years—the value we used in the calibration.

In order to make our case, heavily influenced by a literature that developed during the decade following the default episodes of the 80s, most notably Dooley (1995), Seidman (2000) and Edwards (1988), we need to briefly review the mayor events in international financial markets since the 70s.[10]

During the Bretton-Woods period, international financial markets were dominated by official lending to developing countries. The change came about after the massive wealth redistribution across countries that followed the oil shock of the early 70s. The oil rich countries amassed huge savings, and governments of developed economies were reluctant to intermediate and redirect these

[10]For further details, see Doolye (1995)

funds to emerging economies. As Dooley (1995) mentions in his introduction (Pg. 263):

"One of the keys to the interpretation of the debt crisis...is that the emergence of banks as financial intermediaries in the 1970s can best be understood as a process in which the banks replaced the governments of industrial countries as lenders to developing countries but did so with the approval, encouragement, and implicit support of the governments of the industrial countries."

There is little doubt that the exposure of several mayor US Banks to Latin-American debt was beyond prudent bank management. In this regard, Dooley explains (Pg. 266):

"Officials of the Federal Reserve System, for example, were concerned about the size of the banks' exposure. As early as 1974, Arthur Bums (1978), then chairman of the Federal Reserve Board, warned that banks were taking excessive risks in international lending. Governor Henry Wallich (1981, 1987) repeatedly pointed out before 1982 that the banks' exposure to sovereign risk threatened their capital and argued that additional lending should be constrained by the regulatory authorities."

Banking regulatory decisions also have a bearing on the 1980s debt crisis. For example, loans to a single borrower could not exceed 10 percent of bank's capital; nevertheless, regulators allowed different government agencies in foreign countries to be considered as different borrowers. As a consequence, the exposure to a single country exceeded the limit of 10% in many occasions.

In addition, there is evidence suggesting that Banks were encourage by official sources to engage in lending to Latin-American countries. For example, Lewis William Seidman, former head of the U.S. Federal Deposit Insurance Corporation claims in Seidman (2000) that there were non-profit maximizing incentives for lending during the 1980s:

"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."

In a similar line, Edwards (1988) mentions (Pg. 8):

"Perhaps the main inefficiency of the system was that international banks failed to exercise the prudence traditionally associated with bankers. They massively lent to Latin America in the mid to late-1970s, disregarding issues as important as how the funds were being used (i.e., to finance investment or to fuel capital flight), and whether the countries were following "sound" policies. Indeed, in the process of competing to recycle the abundant petrodollars the banks literally "pushed" loans down the throats of the Latin American countries."

And Dooley adds (Pg 266):

"Wellons (1987) documents the cautious approach taken by U.S. regulators in defining limits on lending to individual developing countries and argues that U.S. bank regulators responded to strong political pressure against interfering with recycling to developing countries by declining to enforce such lending limits."

As a consequence, it was only natural that Banks reacted to the crisis by immediately trying to involve their own authorities in the process. Evidence that banks went long with what clearly appears as lack-of-prudence lending is quite limited, with Seidman's quote above being the only explicit reference we found. However, the key ingredient of our argument, is that, independently of what Banks expected ex-ante, they had all the incentives to engage in war a attrition game with their own governments ex-post. This three agent game would allow them to minimize the losses in their portfolios. And it appears that strategy paid off.

In addition, it was also in the best interest of the US regulators to delay an agreement between the countries and the Banks that would make explicit the losses of the Banks. The reason being that, after several other countries followed Mexico and defaulted on its debts, the total accumulated loss for the Banks could have triggered a banking crisis in the United States. Mexico's default on itself may have not jeopardized the US banking system. However, the chain reaction sparkled by Mexico's default certainly did. Mexico alone may not have been in a position to trigger the "too big to fail" doctrine. But the Latin-American region certainly was.

Along these lines, Seidman (2000) also argues that the renegotiation for Mexico took longer than the expected and that can partly be blamed on US regulators that did not allow banks to write down their default debt:

"Had these institutions been required to mark their sometimes substantial holdings of underwater 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."

The unreasonable dependence of the main US Banks on Latin-American government debt was so dramatic, that the matter took the direct attention of Paul Volcker over a period of several months. In the authorize biography of Volcker three page Prologue, that summarizes the main events in Volcker's professional life, William Silber[11] writes:

"In 1982, when skyrocketing interest rates threatened to bankrupt Mexico and impair the capital positions of America's largest banks, Volcker papered over the problem with questionable loans"

(QUOTE: Siber, William (2012). "Volcker. The Triumph of Persistency" Bloomsbury Press.)

The problem that the Latin American defaults caused on the US banking system were so relevant, that the concerns regarding the stability of the US financial sector weighted with enough strength against the tightening required to end inflation, the core objective of Volcker's first term in office, and the main reason why he is so well remembered as a Fed Chairman. As explained in detail in Siber (2012), Volcker's concerns with the emerging risks in financial markets were aired as early as May 1982, several months before the August crisis that ended in Mexico's default. Indeed, at the May 18th, 1982 FOMC meeting, Volcker said:

"We face the possibility of surprises and uncertainties...I'd like to get the interest rates down, [and] it wouldn't hurt my feelings at the very least to give the market a little sense of a lid in that direction"

(Transcript, FOMC Meeting, May 18th, 1982, pg 41.)

By early August, reserves at the Banco de Mexico were very low and the prospect of a default on USA Bank loans was quite likely. As Siber (2012) accounts:

"Volcker understood the consequences better than anyone did. He though that a default by Mexico would damage the biggest names in banking...and could lead to a run in the banking system like that of the 1930".

These fears were explicitly made by Volcker in the FOMC meeting of October 5th, 1982 (See page 19 of the Transcripts of the meeting). But his concern with the potential crisis had been with him way before that meeting. In a document entitled "U.S. Bank Claims on Mexico (end-1981: adjusted for guarantees)", which belongs to the collection of Personal Papers of Paul Volcker, he calculated that the five largest institutions in terms of total assets would loose between 35 and 73 percent of their capital to a Mexican default, and that the next five would loose between 26 and 50 percent. In fact, as Siber (2012) explains in details, Volcker had been closely following

[11] The discussion that follows heavily borrows from Siber (2012) that contains a very rich and fascinating discussion of the events we are concerned about - and all other events related to Volcker's life. A must read!

developments in Mexico since their balance of payments crisis of February 1982. He even arranged for two Central Bank swaps lines to provide liquidity to the Bank of Mexico, involving in August of the same year his network of central bankers in the United Kingdom, Switzerland in Japan among others. And helped arranged a meeting between the finance minister of Mexico, Silva Herzog, and representatives of the main U.S. commercial banks. According to Silber (2012), Volcker even asked officials of the New York Fed to host the meetings. Mexico got a relief from the Banks during that meeting. A few days after, at the FOMC meeting in August the 24th, 1982, Volcker said:

"We are in a very sensitive period... And not just economically, but in terms of the markets...and in fact concern—and I am afraid to some degree justified concern—about the stability of the banking system. I am sure this is the time to be delicate and sensitive. .. I don't think we can be overly mechanical".

(Transcript, FOMC Meeting, August 24th, 1982, pg 18.)

This is a clear indication of Volcker's concern for the stability of the financial sector in the banking system. Together with his comments in the May 1982 FOMC meeting mentioned above, it clearly indicated a potential easing of policy, driven by the health of US banks. At the same August meeting, Henry Wallich, then a member of the Board of Governors, raised the concern of stimulating too much, at a time in which the battle against inflation had not been won yet.

Then, at the October 5th FOMC meeting, Volcker eventually decided in favor of the financial stability objective. He addressed the committee by saying:

"There is a substantive need for a relaxation of pressures in the private markets in the United States... Extraordinary things may have to be done. We haven't had a parallel to this situation historically except to the extent that 1929 is a parallel."

(Transcript, FOMC Meeting, October 5th, 1982, pg 19.)

According to Siber (2012), the reference to the Great Depressions was important to get a favorable vote of 9 against 3 to explicitly target a lower interest rate as the objective of monetary policy. This marked the abandonment of a two year strategy of targeting monetary aggregates and, at the same time, explicitly adopting a softer monetary policy. Thus, in this perceived balance between inflation and financial markets stability, Volcker leaned towards the later. This was a pretty bold move. By October 1982, inflation had indeed dropped dramatically, but the high inflation years were still very vivid in everybody's memory. And so they were the years right after 1976, when after a substantial drop in inflation, and a perception of a quick loosening of monetary policy during 1976 and 1977, inflation jumped up again to its highest value since the inflation that followed the end of WWII.

Indeed, the policy decision faced criticism beyond the 3 negative votes within the committee. Prominent monetary economist Alan Meltzer showed his strong skepticism in an Op. Ed. in the October 12th edition of the New York times. In the end, fears of a return of inflation did not materialized. But from the viewpoint of October 1982, that was a policy trade off that no central banker wants to face.

The problems created in the US banking system were so prominent that Volcker himself was summoned for a formal hearing in Congress in February 1983. Volcker involvement with the banking crisis preceded his role as Chairman of the Fed. From 1975 to 1979, he was the president of the New York Fed. As such, he shared responsibility in the supervision of US banks, including many of those involved in substantial lending to Latin American countries. His responsibilities obviously increased as he became Chairman in 1979. During the hearings, he acknowledged that the banking system faced:

"...an unprecedented threat....we haven't had to deal with during the poswar period"

(International Debt: Hearings Before the Senate Subcommittee on International Finance and Monetary Policy of the Committee on Banking, Housing and Urban Affairs, 98th Congress, 1st Sess., February 14th, 1983, pg 258).

Senator John Heinz, chairman of the Subcommittee, started the Hearings saying:

"The U.S. bank debt problems would not have gotten to their present dangerous stage had our bank regulators not being asleep at the switch"

(Ibid, pg 237)

Senator William Proxmire, a member of the Subcommittee added:

"Even though danger signals were apparent to all but the willfully obtuse, U.S. banks increased their exposure in Mexico during the first half of 1982 by $3.8 billion"

(Ibid, pg 237)

Being asked if the regulators were forcefully enough, Volcker acknowledge:

"I suppose, in retrospect, probably not."

(Ibid, pg 237).

Volcker explained in the personal interviews with Siber that:

"Commercial bankers understand when a bank examiner gives them a green light to lend. They also respond to a red light, wether they like it or not, but most ignore the cautionary yellow. Sometimes it seems as though bankers even accelerate their lending when they see yellow, to avoid getting left behind, like drivers flooring the gas pedal before the light turns red"

(Silber 2012, pg. 227).

Volcker's dual record was noted by former Fed Chairman William McChesney Martin in an Op. Ed. that came after the failure of Continental Illinois:

"...very good on monetary policy [and] a complete flop on bank supervision."

(New York Times, December 10, 1985).

Volcker's reaction, in the personal interviews with Silber reacted:

"A complete flop is a little harsh, but it hurts all the more because Bill Martin is a personal hero of mine. I clearly had more work to do on bank supervision - but also on monetary policy."

We now discuss how the events mentioned so far conditioned the game Mexico had to play after the default. Dooley mentions (Pg. 270):

"The initial reaction to the banks' refusal to roll over credits was as expected. .., there were immediate calls on the governments of the creditor countries to provide the debtor governments with the means to meet their obligations to the banks. ..., bank regulators in all the industrial countries reassured the markets that they would not close banks the capital of which was threatened by losses on developing-country loans. But the surprise was that the creditor governments refused to provide the banks with an opportunity to sell their doubtful credits to their governments on any terms, favorable or not."

This started a protracted period of negotiations that had no way to solve the problem, mostly due to the standoff between the Banks and the US regulators. Again, quoting Dooley (pg. 271):

"...the events following the debt crisis cannot be adequately modeled as a game involving only debtors (developing-country governments) and creditors (commercial banks). By leaving out the interested and relatively wealthy third parties (industrial country governments), this framework fails to capture the basic nature of the problems generated by the crisis."

and he adds (pg. 272):

"The struggle that followed between the official and private foreign creditors left the debtors without a basis for entering into credible contracts with new creditors."

This game between creditors evolved in clear favor of Banks. According to Dooley (Pg. 272), in 1982, debtor countries owed about $280 billion to the banks and another $115 billion to official creditors. By the end of the decade, the real value of the debt to the banks was close to $240 but the real value of official debt went up to about $ 240. The bank debt numbers are consistent with countries paying fully the nominal value of the interest during these years, in which case the nominal value of the debt would have remained constant. With an accumulated inflation rate of roughly 20 percentage points, the real value of a $280 debt would become about $230 billion, very close to the number observed at the end of the 80s. How did the countries paid for all those interests? Probably partly with the positive trade balance observed during some of those years, but surely by borrowing from institutional lenders, which explains the substantial increase in the real value of this type of debt.

The end game was formally announced as the Baker plan. It involved, in Dooley's words (Pg. 275):

"The essence of the plan was that industrial-country governments would provide (a little) new lending to the debtor countries, both directly and through the international institutions they both financed and controlled, and would thereby "catalyze" (a large volume of) new credits from the banks."

Dooley finally concludes (pg. 276):

"Neither the banks nor the creditor governments, however, saw any advantage to presenting their position with excessive clarity. Banks were winning the game as it was being played, and governments that had asserted they would not "bail out the banks" were not anxious to concede that they were doing slowly what they would not do quickly."

Modeling the much more complicated game between Mexico, the Banks and the US government is way beyond the scope of the paper. But we believe that Dooley's case in favor a substantial change in the game Mexico was involved is quite strong. Thus, we find it conceivable that the relevant parameter for the probability of a re-negotiation in Mexico in 1982 was substantially lower than 1 every 5 years used in the benchmark calibration, that is affected by the ex-post events. As supporting evidence, it should be noted that the Mexican government first approached the Banks only six months after the default, in order to renegotiate terms and resume payment. Note also that the average number reported by Gelos, Sahay, and Sandleris (2011) is one every five years for events studies in the 1980s. Thus average includes the defaults of the 80's, that lasted between 8 and 12 years, but it is substantially lower. Clearly, the defaults of the 80s stand out by being particularly longer than other episodes in history.

In fact, the most dramatic default episode in Latin-America post Brady plan was probably the one in Argentina in 2002. That default was declared after a depression of more than 20%, measured as a percentage from the previous peak in 1988. By 2005, at a time in which the economy had not yet fully barely recovered the per-capita level of 1998, Argentina made the first offer to swap the old bonds for new ones, that was accepted by over 75% of the bond holders. That was only three years after the default.

The length of the default period is essential in the theory, since the key mechanism is that in defaulting, the government expects that the bargaining game will be played when the interest rate is still high. Thus, a key interaction for the mechanism to play an important role, is the persistency of the interest rate shock—the more persistent, the stronger the mechanism - and the likelihood of a fast renegotiation opportunity—the higher the likelihood, the stronger the mechanism. If we are correct, then the benchmark calibration underestimates the role of the re-negotiation mechanism.

5.1 Quicker renegotiation

We therefore conclude this section by exploring the sensitivity of our results to changes in the parameter that govern the probability of having a bargaining opportunity. In Table 5 we report the results of the same calibrated model, but using an implied expected chance to renegotiate to arrive once every two years. We believe that this is number is closer to what Mexico could expect in 1982.

Table 5: Probability of interest-rate hikes triggering a default

	No renegotiation, no recovery	Fixed exogenous haircut	Endogenous renegotiation
$\Pr(\text{default event}\mid\text{interest-rate hike}, \theta = 0.192)$	0.06	0.13	0.24
$\Pr(\text{default event}\mid\text{interest-rate hike}, \theta = 0.5)$	0.08	0.25	0.47

In all cases the probability of an interest rate hike triggering a default is larger, which makes the case for the Mexican default in 1982 even stronger. This is due to a lower penalty from a shorter exclusion from financial markets. Introducing renegotiation increases this probability because of the higher likelihood of favorable haircuts with high interest rates. The increase is even higher with a higher value of θ, which highlights the interaction between the persistence of high interest rates and the expected quick arrival of a renegotiation opportunity.

Figure 8: Paths around default events

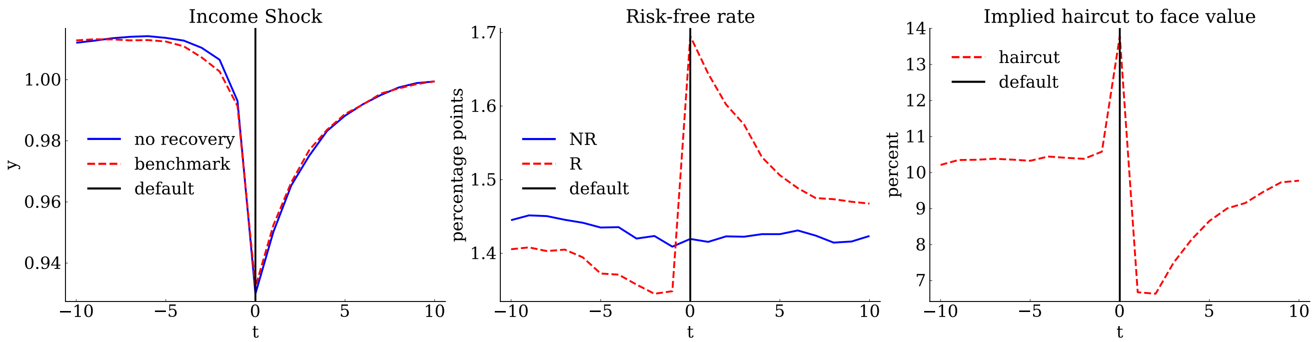


Figure 6 is the analogous of 6 for this alternative exercise with higher θ. As was the case in the benchmark calibration, the implied haircut (the haircut that the government would get if it were to default in the given period) sharply increases on default episodes. This increase is driven by higher interest rates which, given their persistence, are expected to remain high when a renegotiation occurs.

6 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.

References

Aguiar, Mark and Gita Gopinath. 2006. "Defaultable debt, interest rates and the current account." *Journal of international Economics* 69 (1):64–83. 3

Arellano, C. 2008. "Default risk and income fluctuations in emerging economies." *American Economic Review* . 3

Arellano, Cristina, Xavier Mateos-Planas, and Jose-Victor Rios-Rull. 2022. "Partial Default." *Journal of Political Economy (accepted)* . 3

Asonuma, Tamon and Hyungseok Joo. 2020. "Sovereign Debt Restructurings: Delays in Renegotiations and Risk Averse Creditors." *Journal of the European Economic Association* 18 (5):2394–2440. 3

Asonuma, Tamon, Dirk Niepelt, and Romain Ranciere. 2023. "Sovereign bond prices, haircuts and maturity." *Journal of International Economics* 140:103689. 22, 23, 24, 40, 41

Asonuma, Tamon and Christoph Trebesch. 2016. "Sovereign Debt Restructurings: Preemptive or Post-Default." *Journal of the European Economic Association* 14 (1):175–214. 4

Bai, Yan and Jing Zhang. 2012. "Duration of sovereign debt renegotiation." *Journal of International Economics* 86 (2):252–268. 3

Benjamin, David and Mark L. J. Wright. 2009. "Recovery Before Redemption: A Theory of Delays in Sovereign Debt Renegotiations." 2, 3

Benjamin, David and Mark L J Wright. 2018. "Deconstructing delays in sovereign debt restructuring." *Oxford Economic Papers* 71 (2):382–404. 3

Chatterjee, S. and B. Eyigungor. 2012. "Maturity, indebtedness, and default risk." *American Economic Review* . 3, 12

Dvorkin, Maximiliano, Juan M. Sanchez, Horacio Sapriza, and Emircan Yurdagul. 2023. "Sovereign Debt Restructurings." *American Economic Journal: Macroeconomics (forthcoming)* . 3

Gelos, R. Gaston, Ratna Sahay, and Guido Sandleris. 2011. “Sovereign borrowing by developing countries: What determines market access?” *Journal of International Economics* 83 (2):243–254. 16, 34

Guimaraes, Bernardo. 2011. “Sovereign default: Which shocks matter?” *Review of Economic Dynamics* 14 (4):553–576. 2, 4

Hatchondo, J.C. and L. Martinez. 2009. “Long-duration bonds and sovereign defaults.” *Journal of International Economics* . 12

Hatchondo, J.C., L. Martinez, and Sosa-Padilla. 2014. “Voluntary sovereign debt exchanges.” *Journal of Monetary Economics* . 4, 13

Johri, Alok, Shahed Khan, and CÃ©sar Sosa-Padilla. 2022. “Interest rate uncertainty and sovereign default risk.” *Journal of International Economics* 139:103681. 4

Mihalache, Gabriel. 2020. “Sovereign default resolution through maturity extension.” *Journal of International Economics* 125:103326. 4

Negrete Cardenas, Sergio. 1999. “Mexican debt crises: a new approach to their genesis and resolution.” *MS, University of Essex* . 16

Ocampo, José Antonio. 2014. “The Latin American Debt Crisis in Historical Perspective.” In *Life After Debt: The Origins and Resolutions of Debt Crises*, edited by Joseph E. Stiglitz and Daniel Heymann, chap. 2.1. Houndmillis: Palgrave Macmillan, 87–115. 1

Pitchford, Rohan and Mark L. J. Wright. 2011. “Holdouts in Sovereign Debt Restructuring: A Theory of Negotiation in a Weak Contractual Environment.” *The Review of Economic Studies* 79 (2):812–837. 3

Reinhart, Carmen M. and Kenneth S. Rogoff. 2009. *This Time Is Different*. Princeton: Princeton University Press. 1

Singh, Anurag. 2020. “Clustered Sovereign Defaults.” 4

Sturzenegger, Federico and Jeromin Zettelmeyer. 2008. "Haircuts: Estimating investor losses in sovereign debt restructurings, 1998–2005." *Journal of International Money and Finance* 27 (5):780–805. 2, 22, 23, 39

Tourre, F. 2017. "A Macro-Finance Approach to Sovereign Debt Spreads and Returns." *Doctoral dissertation, The University of Chicago* . 1

Yue, Vivian Z. 2010. "Sovereign default and debt renegotiation." *Journal of International Economics* 80 (2):176–187. 3

A Haircuts measures

Following Sturzenegger and Zettelmeyer (2008), the haircut for a debt instrument i exchanged for another instrument e is:

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

where $NPV\left(r, x\right)$ 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.

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 only the face value b is renegotiated in the model, and the maturity rate γ and coupon structure are fixed. Therefore, for each haircut observed in the data, we calculate its model equivalent that considers our simplifying assumptions and benchmark calibration.

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

$$NPV^d\left(r_e, x_i^d\right) = \sum_{t=0}^{\infty}\left(\frac{1}{1+r_e}\right)^t\left[\prod_{s=0}^{t}\left(1-\gamma_{i,s}\right)\right]\left[\gamma_{i,t} + z_{i,t}\left(1-\gamma_{i,t}\right)\right] b_i \tag{21}$$

where $x_i^d = \left(b_i, \gamma_{i,0}, \gamma_{i,1}, \ldots, z_{i,0}, z_{i,1}, \ldots\right)$. In the model, $\gamma_{i,t} = \gamma$ and $z_{i,t} = 0$, for all i, t, are fixed parameters, so the analogous expression is:

$$NPV^m\left(r_e, x_i^m\right) = \sum_{t=0}^{\infty}\left(\frac{1-\gamma}{1+r_e}\right)^t \gamma b_i = \gamma b_i \frac{1+r_e}{\gamma + r_e} \tag{22}$$

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

$$NPV^m\left(r_e, \left(b^R, \gamma\right)\right) = \gamma b^R + q^R\left(1-\gamma\right) b^R = \gamma b^R \frac{1+r^e}{\gamma + r^e} \tag{23}$$

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:

$$h^{SZm} = 1 - \frac{\gamma b^R \frac{1+r^e}{\gamma+r^e}}{\gamma b \frac{1+r^e}{\gamma+r^e}} = 1 - \frac{b^R}{b} \tag{24}$$

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 a model face value b_i, for each observed $NPV^d\left(r_e, x_i^d\right)$, by combining equations (21) and (22):

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

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.

B Robustness

Table 6 presents the estimation of equation (20) using SZ-haircuts as a dependent variable. This table shows that the positive relationship between haircuts and interest rates remain positive and statistically significant in all specifications with the relevant controls considered by Asonuma, Niepelt, and Ranciere (2023): the remaining time to maturity at the time of the exchange, the coupon rate of the instrument if it is fixed, and an indicator variable on whether the instrument has a floating coupon rate. Each additional percentage point in risk-free rates increases haircuts by between 6 and 7 percentage points.

Table 6: 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

Table (7) presents the estimation of equation (20) using as a dependent variable the model equivalent haircuts. The same level of robustness is maintained in our findings when using the alternative measure of haircuts, which incorporates the simplifying assumptions inherent to our model: fixed maturity and coupon structure. 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. Indeed, for each specification, the regression using the model haircuts estimates a higher effect of real risk-free rate compared to the analog regression using SZ-haircuts. Our results are also consistent with the main findings of Asonuma, Niepelt, and Ranciere (2023): haircuts are lower for longer maturity bonds.

Table 7: 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