# The Role of Penalties for Sovereign Default Expectations: Evidence from the Courts*

Lennart Niermann

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**Abstract**

Why do sovereigns repay foreign creditors when external enforcement is weak? This paper shows that direct economic default penalties - not just exclusion from financial markets - are a key determinant of repayment incentives. I exploit quasi-exogenous variation in the cost of default generated by US court rulings in sovereign default litigation. Identification comes from high-frequency responses in third-country sovereign bonds governed by US law whose issuers are not parties to the litigation. I find that a one percentage point increase in the recovery rate lowers the default probability by 19 basis points. I interpret these results in a dynamic model of international borrowing with endogenous default and endogenous debt recovery rates. Calibrated to match the empirical relationship between recovery and default, the model implies that a one percentage point increase in the cost of default lowers the default probability by 7.9 basis points. I find that higher default penalties can be welfare improving. This offers an explanation for why many emerging markets have been pursuing high-debt-high-default-cost regimes, heightening financial instability under probabilistic tail events.

JEL CODES: E6, F34, H12, H6

Keywords: Debt crisis, Default Penalties, Beliefs, External Debt

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Niermann: Faculty of Economics, University of Cambridge. lcn29@cam.ac.uk

# 1 INTRODUCTION

Why do sovereigns repay foreign creditors when external enforcement is weak? This question lies at the core of the sovereign debt literature. Seminal work by Eaton and Gersovitz (1981) proposes that the key enforcement device is exclusion from financial markets. In response, Bulow and Rogoff (1989) rebutted that exclusion alone is insufficient to explain sustained positive net debt, but must rather be supported by direct sanctions. This kicked off a long-standing literature on the role of direct default penalties underpinning sovereign repayment incentives. While extensive, most of this literature is theoretical, and many mechanisms have not been brought to the data rigorously (Trebesch, 2023).

This paper provides novel empirical evidence that the size of the economic cost of default is a key determinant of sovereign repayment incentives. I exploit quasi-exogenous variation in the expected cost of default generated by U.S. court rulings and case resolutions in sovereign debt litigation. Identification rests on four institutional features of international lending. First, creditor litigation has become an integral component of sovereigns' cost of default. Second, a large share of emerging market debt is raised under a common jurisdiction, namely New York law. Third, legal shocks to New York law have historically generated variation in sovereigns' expected litigation-induced cost of default. Fourth, legal shocks against one country can establish precedent for litigation against other countries issuing debt under the same jurisdiction. Taken together, these features allow me to study spillover effects of legal shocks to third-country sovereigns whose bonds are similarly governed by U.S. law, but who are not parties to the litigation itself.

The empirical analysis proceeds in two steps. First, I recover daily market-implied recovery rates and default probabilities from the cross section of U.S.-dollar-denominated sovereign bonds, following the structural bond-pricing approach of Vrugt (2011) and Merrick (2001). Recovery rates serve as my empirical proxy for the cost of default, consistent with a bargaining framework in which stronger default penalties improve creditors' expected recovery in the event of default.[1] Second, I examine how recovery rates and default probabilities move in narrow event windows around legal shocks, focusing on third-country sovereigns exposed to New York-law borrowing. I find that a one percentage point increase in the recovery rate lowers the one-year default probability by 19 basis points. The effect is robust to the inclusion of sovereign fixed effects, trade controls, alternative event windows, outlier exclusion and does not appear to be mechanically generated by the joint estimation procedure, as shown by Monte Carlo exercises.

To interpret this evidence further, I develop a dynamic model of international borrowing with endogenous sovereign default and endogenous debt recovery rates. In the model, a defaulting government bargains with creditors over debt restructuring, and default entails a temporary economic penalty in the form of output losses. Higher default penalties strengthen creditors' outside option in renegotiation, raise equilibrium recovery rates, and reduce the set of states in which default is optimal. In line with my empirical findings, I can show in general that in a partial equilibrium, higher recovery rates should lower default probabilities. I can further show that under the model, recovery rates are increasing in the default penalty. This validates choosing them as a proxy for default costs in the empirical section. I then calibrate the model to match the empirical relationship between recovery and default risk identified in the data. The calibrated model allows me to translate changes in the empirical recovery rate into underlying changes in the economic cost of default and to quantify their implications for default probabilities and sovereign bond yield spreads. Under the model, a one percentage point increase in the cost of default lowers the default probability by 7.9 basis points.

This paper provides direct empirical evidence on the long-standing question of whether economic default penalties sustain sovereign repayment. Taken together, the results suggest that direct default penalties are not merely a theoretical refinement, but a quantitatively important force shaping sovereign repayment incentives and bond pricing. I further find that

[1] The economic cost of default is not easily observable at a high frequency. I show that under a model of endogenous recovery rates and sovereign default, recovery rates are increasing in the cost of default. In a more restricted version of the model I can also show this analytically. Thus, empirically, I proxy changes in the underlying cost of default by changes in the observable recovery rate.

under the model, higher default penalties can be welfare improving as they mitigate limited commitment on the government side, which reduces borrowing costs and increasing sustainable debt capacity. This offers an explanation for why many emerging markets have been pursuing high-debt-high-default-cost regimes in the recent past, even though this comes at the cost of heightening financial instability under probabilistic tail events.

**Related Literature.** This paper speaks to two strands of the sovereign debt literature: (i) enforcement and the costs of default, (ii) legal institutions and creditor litigation.

A first strand studies why sovereigns repay in the absence of supranational enforcement. Eaton and Gersovitz (1981) emphasize exclusion from international capital markets as the main disciplining device, an approach extended to stochastic and long-run environments by Aguiar and Gopinath (2006) and Arellano (2008). Bulow and Rogoff (1989), however, argue that exclusion alone cannot sustain positive net foreign debt and must be complemented by direct sanctions. Subsequent frameworks proposed endogenous default penalties arising from output or financial frictions – for example, through disrupted trade and production (Mendoza and Yue, 2012) or a damaged domestic banking system (Sosa-Padilla, 2018). Empirically, Furceri and Zdzienicka (2012), Sturzenegger (2002), Hébert and Schreger (2017), and Borensztein and Panizza (2009) estimate sizable medium-run output losses after default, but identification is challenging because crises and defaults are jointly determined, and it remains unclear what role such penalties play for government incentives to repay. Trebesch (2023) surveys this literature and stresses that much of the discussion about direct default costs remains theoretical. In contrast, this paper provides high-frequency causal evidence on how economic penalties affect market-perceived default probabilities by exploiting quasi-experimental legal shocks and bond price data.

A second, closely related strand focuses on legal institutions, contract design, and creditor litigation as specific channels through which default penalties materialize. Since the Foreign Sovereign Immunities Act in the United States and similar legislation in the United Kingdom, sovereigns issuing under foreign law have become increasingly exposed to attachment of assets and disruptive legal strategies by holdout creditors (Schumacher et al., 2021). This has spurred work on holdouts, pari passu clauses, and the effectiveness of collective action clauses in shaping bargaining power and recovery values in restructurings (e.g. Pitchford and Wright (2012); Cruces and Trebesch (2013); Chamon et al. (2018)). Yue (2010) formalizes debt renegotiation as a Nash bargaining problem and shows how default penalties map into recovery rates. I build on this by exploiting variation in default costs stemming from creditor litigation in our empirical exercise.

**Outline.** The rest of this paper is structured as follows. Section 2 proceeds to provide empirical evidence on the causal effect between changes in the recovery rate induced by exogenous changes in the cost of economic default and markets' beliefs about default probabilities. Section 3 introduces the model of international borrowing with endogenous default and endogenous recovery rate. It provides analytical model results and calibrates the model, matching the empirical relationship between recovery rate and default risk from the empirical section. It then presents the link between changes in the economic cost of default and the default probability under the model. It also discusses welfare- and policy implications. Section 4 concludes.

## 2 EMPIRICAL EVIDENCE

In this section, I estimate how changes in the expected default penalty affect sovereign default risk. Empirically, I proxy the default penalty using expected recovery rates, defined as the share of bond principal creditors expect to recover in the event of default or restructuring. Section 3 formalizes the mapping between the default penalty and creditor recovery.

Identification rests on four institutional features of international lending. First, creditor litigation has become an integral component of sovereigns' cost of default. Second, a large share of emerging market debt is raised under a common jurisdiction, namely New York law. Third, legal shocks to New York law have historically generated variation in sovereigns' expected cost of default. Fourth, legal shocks against one country can establish precedent for litigation against other countries issuing debt under the same jurisdiction. Taken together, these features allow me to study the high-frequency response of third-country sovereign bond markets to legal shocks arising in cases against other sovereigns. The identifying idea is that such shocks plausibly generate exogenous variation in expected cost of default for third-countries exposed to New York-law borrowing due to the legal precedent these shocks set.

The following section discusses in detail the institutional background of international lending that enables my empirical analysis.

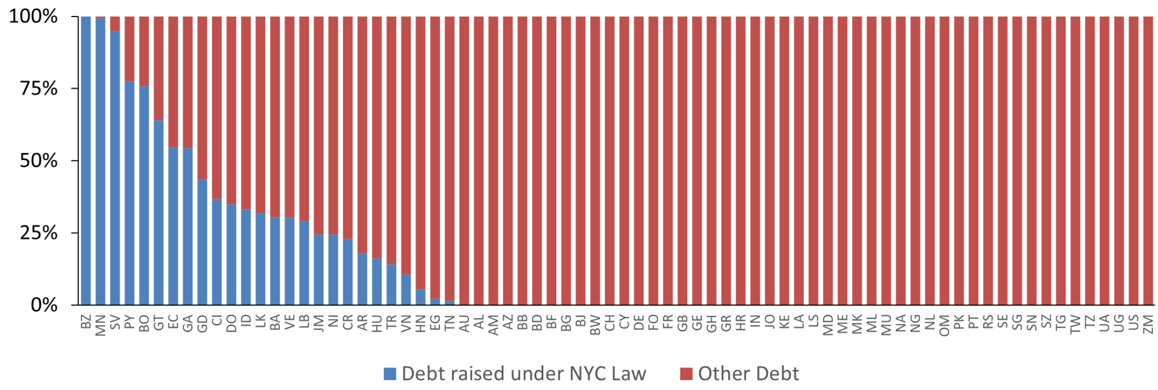
**Role of Creditor Lawsuits.** Private creditor litigation has become an important component of sovereigns' ex post cost of default (Schumacher et al., 2021). The Republic of Congo provides a useful example. In the early 2000s, several US-based debt funds launched attachment attempts on Congo's crude oil exports and successfully blocked Congo from receiving royalties or export revenues - Congo's most important source of foreign exchange - for multiple years (Schumacher et al., 2021). Other litigation strategies have targeted state-owned enterprises or sovereign assets, including naval vessels, presidential planes, satellite launches, and blocked repayments to other restructured creditors. These cases suggest that legal risk can be an important deterrent to default. Venezuela provides another illustration, where the sovereign continued to service bond payments in full and on time until mid-2017, despite a lack of basic food and medicine and despite defaulting on most other creditors. According to press reports, legal risks were the main reason why the gopvernment continued to service its bonded debt.[2]

**Common Jurisdiction.** A substantial share of emerging market sovereign debt is issued under New York law (Trebesch et al., 2012). Figure (1) shows that as of January 1, 2016, twenty-seven countries issued sovereign bonds governed by New York law.[3] Weighted by issue amount, these countries' shares of sovereign bonds under New York law ranged from

[2]"The government is desperate to avoid defaulting on its debt, since that would lead to creditors seizing oil shipments and assets abroad." - The Economist on July 29, 2017.

[3]I choose 2016 to visualize countries exposure to debt governed by New York law, as 2016 is the year with the highest density of legal shocks in my sample as I will discuss in section 2.2.

FIGURE 1: WEIGHTED SHARE OF BONDS GOVERNED BY NEW YORK LAW (2016)




Note: Data is based on the universe of active sovereign bonds as of January 1, 2016. Shares are weighted by bonds' outstanding amounts.

0.005 to 100 percent.

**Legal Shocks.** I define a legal shock as either (i) a ruling by the U.S. District Court for the Southern District of New York, the U.S. Court of Appeals for the Second Circuit, or U.S. Supreme Court in a sovereign debt litigation case, or (ii) the resolution date of a sovereign debt litigation case filed in either of these courts. Case resolution can take the form of either a court ruling or an out-of-court settlement between the sovereign and the plaintiff.

Court rulings and settlements affect the economic cost of default through distinct channels. Rulings change the legal viability of specific enforcement strategies, while settlements reveal the expected returns to pursuing holdout litigation rather than participating in a restructuring. Thus, rulings can be thought of as affecting the cost of default on the intensive margin, while settlements affect the extensive margin by signaling how profitable litigation would be.

There is a rich history of such legal shocks under New York law (Schumacher et al., 2021; Hébert and Schreger, 2017). Two cases illustrate these mechanisms. First, *CIBC v. Banco Central do Brasil* was one of the first cases in which a fund earned substantial profits by purchasing distressed sovereign debt on the secondary market and subsequently recovering most of the principal plus interest through litigation. The case weakened the so-called *Champerty* *defense*, under which purchasing bonds primarily for the purpose of filing suit was impermissible, and thereby increased the feasibility of specialized holdout litigation. This enabled a new class of specialized plaintiffs to take over existing claims, increasing the cost of default. Second, the settlement in *NML Capital v. Argentina* in 2016 stands out as one of the largest holdout successes to date, with more than $10 billion paid to holdout creditors and reported returns exceeding 300 percent, in some cases approaching 1,000 percent. Such outcomes can raise creditors' ex ante expected returns to litigation in future sovereign restructurings, making it more likely that creditors litigate after being defaulted on.

**Legal Precedent.** Because U.S. jurisprudence is precedent-based, legal developments in one case can be relevant not only for the litigating sovereign, but also for other sovereigns that issue debt under New York law. Court rulings can establish precedent on the legal viability of specific enforcement strategies, while large settlements can reveal that such strategies are highly profitable in practice. For third-country issuers exposed to New York-law borrowing, these events therefore plausibly shift the expected cost of default through their effect on future creditor enforcement.

## 2.1 Methodology

The previous section laid out why legal shocks under New York law can generate plausibly exogenous variation in the expected cost of default faced by third-country sovereigns. In this section, I present an empirical framework to estimate high-frequency changes in these countries' default probabilities and expected costs of default around legal shocks. Because the expected cost of default is not directly observed at daily frequency, I proxy its movements using changes in the market-implied recovery rate, which Section 3 shows to be monotone in the default penalty under the model.[4] The analysis proceeds in two steps: I first recover

[4]While some papers estimate the economic cost of default directly (see e.g. Hébert and Schreger (2017); Yeyati and Panizza (2011)), relying on conventional approaches at a high frequency is infeasible. Instead I shop that under a model of endogenous recovery rates and default choices, the recovery rate is monotone in the cost of default. Proposition 2 formalizes this mapping in a stylized model environment.

daily estimates of recovery and default risk from bond prices, and then examine how these estimates change around court rulings.

**Estimating Parameters.** To estimate daily default probabilities and recovery rates, I follow Vrugt (2011) and Merrick (2001) by estimating both parameters simultaneously from a daily cross-section of USD-denominated sovereign bonds. The underlying idea is to use the risk-neutral valuation framework of Jarrow et al. (1997) to express the price of an outstanding bond as its discounted, probability-weighted cash-flows. Given that the payment schedules of the USD-denominated bonds in my cross-section are known, and that the discount factor can be inferred from the known U.S. yield curve at the time, one can express the price of an outstanding bond as a function of two variables: the recovery rate, and the default probability.[5] Given a cross section of outstanding bonds issued by the same sovereign on a given date, I recover the default probability and recovery rate by minimizing the distance between observed market prices and model-implied prices. I repeat this procedure for each country in the sample on each trading day over my time horizon.

Concretely, following Jarrow et al. (1997), I assume that the price of a bond issued by sovereign $i$ can be written as the default-probability-weighted sum of promised cash flows and the recovery value (in the following, I am omitting the country subscript $i$ and the date subscript $d$ for legibility):

$$P_0 = \sum_{n=1}^{N} df_n[(CF_n \times S_n) + (RV \times S_{n-1} \times \pi_n)] \tag{1}$$

Here, $N$ is the total number of remaining payments, and $CF_n$ denotes the $n$th such cash flow payment. $RV$ is the recovery value creditors expect to receive in the event of default or restructuring, $df_n$ is the risk-free discount factor for cash flow payment $n$, inferred from the U.S. yield curve. $\pi_n$ is the probability that the sovereign defaults on coupon payment $n$ con-

[5] I focus on USD-denominated bonds, as the pricing of non-USD bonds requires detailed daily data on the respective country's yield curve, for which historical data is sparser and less accurate due to the lower liquidity of emerging markets' bond markets relative to the US.

ditional on its survival up to period $n-1$, and $S_n$ is the cumulative probability of survival related to the history of $\pi$:

$$S_n = \prod_{k=1}^{n}(1-\pi_k) \qquad \wedge \qquad S_0 = 1 \tag{2}$$

The intuition behind this pricing equation is that if the sovereign 'survives' through payment date $n$, the creditor receives a future cashflow $CF_n$ discounted by $df_n$. If the sovereign defaults at payment $n$, the creditor receives the recovery value discounted by $df_n$. The price of a bond therefore reflects the probability-weighted summation over all future cash flow dates.

In line with Vrugt (2011) and Merrick (2001), I allow default risk to vary over time. I assume that the probability of default takes the form:

$$\pi_k = \alpha + \beta \times t_k \tag{3}$$

Here $\pi_k$ is the probability that the government defaults between cash flow payments $k-1$ and $k$, where $t_k$ denotes the time between the two payment dates. The 2-parameter specification of the default probability allows for various slopes in the term structure of default rates.

At each date, I assume that the expected recovery for default occurring in the future is common across all outstanding bonds issued by a given sovereign. Combining equations (1) through (3) results in the bond pricing equation

$$P_0 = \sum_{n=1}^{N} df_n \left[ \begin{array}{l} \left(CF_n \times \prod_{i=1}^{n} \left(1 - \left\{\alpha + \beta \times \left(1 - e^{-t_i}\right)/t_i\right\}\right)\right) \\ + \left(RV \times \prod_{i=1}^{n-1} \left(1 - \left\{\alpha + \beta \times \left(1 - e^{-t_i}\right)/t_i\right\}\right) \times \left\{\alpha + \beta \times \left(1 - e^{-t_n}\right)/t_n\right\}\right) \end{array} \right] \tag{4}$$

This is an equation in three unknowns: $\alpha$, $\beta$ and $RV$. Note that the cash flow schedule for each bond and the associated discount factor are known at every date. If we have a cross-section of $J$ bonds issued by the same sovereign with associated known prices, this yields a system of $J$ nonlinear equations in three unknowns. To solve for the three unknown parameters, I minimize the sum of squares pricing error:

$$\min_{\alpha,\beta,RV} \sum_{j=1}^{J} \left(P_j - \hat{P}_j\right)^2 \tag{5}$$

Here at a given date, $P_j$ is the observed market price of bond $j$, while $\hat{P}_j$ is the fitted price of bond $j$ based on equation (4). By using the Broyden–Fletcher–Goldfarb–Shanno algorithm in the 'optim' optimization suite of R, I minimize this error. On the first day of my sample, I set initial guesses for all three parameters. On every consecutive day, the initial guess for each parameter is the estimate from the previous day.

**Changes Around Court Rulings.** On every day $d$ and for every country $i$, I recover the market-implied recovery rate and the implied term structure of default probabilities using estimated parameters $\alpha$ and $\beta$:

$$\hat{RV}_{d,i} \tag{6}$$

$$\hat{p}_{d,i}(t) \equiv \hat{\alpha}_{d,i} + \hat{\beta}_{d,i} t \tag{7}$$

I then examine how these objects change around a legal shock occurring on date $s$ in a case against sovereign $j$, focusing on third countries $i \neq j$.

For my main specification, I choose a two-day event window, reflecting the day before and after the legal shock, as made explicit in equations (8) and (9). Longer windows mean that the risk of capturing background noise increases. Shorter windows risk not capturing the entire response to the legal shock if effects are not transmitted instantaneously in financial markets. Further, intraday timing is unavailable for most of my legal shocks. In appendix section A.3 I provide some robustness checks that the results of my paper are not driven by the choice of event window. Namely around each legal shock $s$ I estimate

$$\Delta \hat{RV}_{s,i} = \hat{RV}_{s+1,i} - \hat{RV}_{s-1,i} \tag{8}$$

$$\Delta \hat{p}_{s,i}(t) = \hat{p}_{s+1,i}(t) - \hat{p}_{s-1,i}(t) \tag{9}$$

As before, $s$ denotes the date of the legal shock, and $i$ denotes the country for which the parameters are estimated. Further, $s-1$ and $s+1$ represent the first trading day before and after the shock. $\Delta\hat{RV}_{s,i}$ reflects the change in country $i$'s recovery rate around the legal shock $s$, and $\Delta\hat{p}_{s,i}(t)$ reflects the associated change in the default probability as laid out in equation (7).

For all shocks $s$ originating in countries $j$, and for all third countries $i$ such that $i \neq j$, I then estimate $\Delta\hat{p}_{s,i}(t)$ and $\Delta\hat{RV}_{s,i}$ and run the following regression:

$$\Delta\hat{p}_{s,i}(t) \;=\; \gamma_i \;+\; \zeta \times \Delta\hat{RV}_{s,i} \;+\; \boldsymbol{\gamma}'\mathbf{Z}_{s,i} \;+\; \varepsilon_{s,i} \tag{10}$$

Here, $\gamma_i$ denotes country fixed effects. I interpret $\zeta$ causally under the assumption that, within narrow event windows, changes in the estimated recovery rate are driven by the legal shock's effect on expected future creditor enforcement rather than by coincident changes in sovereign fundamentals.

One potential violation of the identifying assumption is that legal shocks in country $j$ may affect third-country default risk through real economic spillovers rather than through legal precedent. This concern is most relevant when countries $i$ and $j$ are strongly integrated through trade: a shock that weakens activity in $j$ could spill over to $i$ through reduced bilateral trade or disruptions in closely linked sectors. I therefore control for bilateral trade integration and both countries' overall trade reliance. In equation 10, $Z_{s,i}$ is a vector of controls including country $i$'s trade reliance, the trade reliance of the shock-origin country $j$, and bilateral trade integration between $i$ and $j$. Data on trade reliance and integration is annual and obtained for the year in which shock $s$ occurs. These controls proxy the intensity of non-legal spillovers from the shock-origin country. If the estimated relationship between changes in recovery and changes in default risk remains stable after including these controls, this makes it less likely that the results are driven by trade-based macroeconomic contagion rather than by the legal channel.

## 2.2 Data

My analysis uses two types of data: (i) legal shocks from sovereign debt litigation cases, and (ii) sovereign bond data for third countries whose market reactions to those shocks I study.

**Legal Shocks.** My series of legal shocks combines two sources. First, I use the series of legal rulings in the case of Republic of *Argentina v. NML Capital* between 2012 and 2014 compiled by Hébert and Schreger (2017). These reflect legal rulings by Judge Griesa, the U.S. Court of Appeals for the Second Circuit, and U.S. Supreme Court on the case. I adopt their event-date definitions for the legal shocks, which are typically based on the creation or modification timestamp in the PDF metadata of the ruling as publicly released.

I further merge this with the litigation dataset of Schumacher et al. (2021), which covers the near-universe of lawsuits filed against defaulting countries between 1976 and 2017. From this source, I retain cases filed in New York after 2000 and define the legal-shock date as the case-resolution date, which typically coincides with either a court ruling or an out-of-court settlement between plaintiff and defendant. Where the two sources overlap, I retain the event dating from Hébert and Schreger (2017) for the Argentina–NML rulings.

Together, these sources yield 73 legal shocks between 2000 and 2018 involving 18 unique sovereign defendants. As reported in Appendix table 7a, Argentina accounts for the largest share of events (30 of 73) , but the shock origins are geographically broad, spanning Latin America, Africa, Asia, and Europe. Further, as shown in Table 7b, legal shocks are distributed fairly evenly over time, with a peak in 2016.

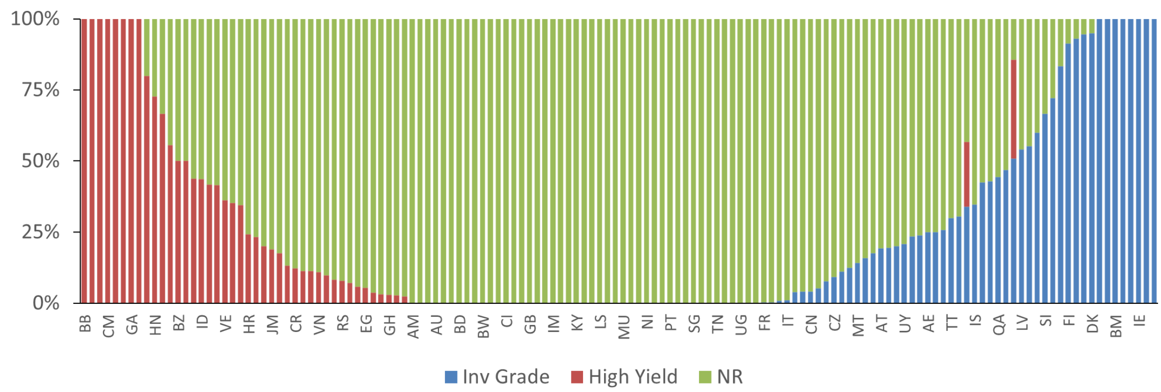
**Bond Markets.** I study the effect of legal shocks on bond markets in countries that do not act as the defendant in the respective legal shock. I restrict the scope of my study to countries that raise a substantial share of their debt under New York law and exhibit some degree of default risk. The former is necessary for U.S. legal shocks to affect the expected cost of default in another country meaningfully. I impose the latter restriction because changes in default penalties are unlikely to have measurable effects in countries whose default premia are already close to zero. In practice, I operationalize these criteria using information on governing law and S&P bond ratings from Bloomberg.

To construct the sample of third countries, I start from the universe of all 19,132 sovereign bonds active on January 1, 2016, obtained from Bloomberg. I focus on 2016, as this is the year with the highest frequency of legal shocks in my sample (Table 7b). For each bond, I collect information on governing law, S&P rating, currency denomination, and outstanding amount. I then compute, at the sovereign level, the outstanding-amount-weighted share of bonds governed by New York law and exclude countries for which this share is below 15 percent (Figure 1).[6]

I next restrict the sample to sovereigns with meaningful default risk. Using S&P ratings, I classify countries according to whether their bond universe contains investment-grade, high-yield, or unrated debt (Figure 2). I retain only countries whose bond universe consists entirely of high-yield and/or unrated bonds, and exclude countries that issue only unrated bonds or have any investment-grade issuance. This leaves an initial set of 21 countries.

To study the market reaction in any of these 21 countries as laid out in section 2.1, I fur-

FIGURE 2: WEIGHTED SHARE OF S&P BOND RATINGS




Note: Data is based on the universe of sovereign bonds as of January 1, 2016. Shares are weighted by outstanding amounts.

[6]This differs from the currency composition of sovereign debt: local-currency debt can be issued under New York law, while foreign-currency debt can be issued under local law.

ther require that each country has at least three active bonds satisfying the following criteria: (i) denominated in U.S. Dollars, (ii) fixed coupon, non-callable, and non-inflation-linked (iii) remaining maturity of more than a month, (iv) daily price data available, and (v) sufficient liquidity, proxied by a Bloomberg Liquidity Assessment score above 50. Daily price data for these bonds is obtained from Refinitiv Eikon. Applying these filters leaves nine countries: Argentina, Côte d'Ivoire, Costa Rica, the Dominican Republic, Ecuador, Guatemala, Indonesia, Paraguay, and El Salvador.

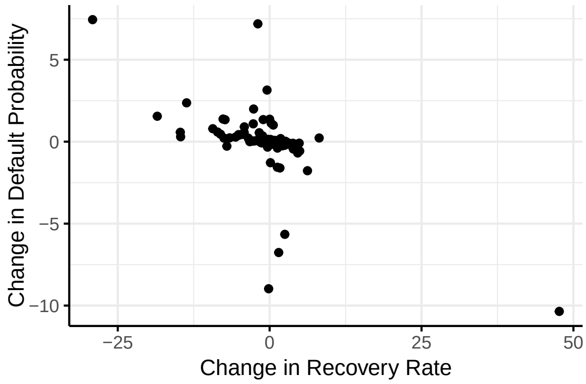
These nine countries have between five and 21 eligible bond series as of January 1, 2016. For previous or following dates, coverage varies. Issuance dates of these bonds range from 1997 to 2016. Maturity dates range from 2016 to 2047. Coupon rates span 2.5 to 12.375 percent, with all bonds paying fixed coupons semiannually. Original issue sizes are substantial. They typically range between $100 million and $2.5 billion, with the median issue amount equaling $1 billion. This suggests that these bonds trade in reasonably liquid secondary markets. Together with the Bloomberg liquidity score, this supports the view that daily price movements contain meaningful information about underlying valuation changes.

I obtain the coupon payment schedule from the bond description on Eikon and cross-check with bond information from Bloomberg. To proxy the risk-free discount factor, I use daily data on the par yield curve rates from the U.S. Department of Treasury. Further, I derive data on countries' annual trade exposure, or bilateral trade integration from the UN Comtrade database.

### 2.3 Results

Using the nine countries identified in Section 2.2, I compute high-frequency changes in the recovery rate and in the term structure of default probabilities around all legal shocks for which sufficient bond-market data are available. Figure 3 visualizes how the high-frequency change in the recovery rate is related to the high-frequency change in the default probability over one year. Each observation corresponds to a shock-country pair, where the country is a third-country sovereign exposed to the legal shock through New York-law borrowing. The

FIGURE 3: HIGH FREQUENCY CHANGES AROUND LEGAL SHOCKS




Note: Estimates are based on 150 shock-country observations across all legal shocks and eligible third-country sovereigns. Changes in the term structure of the default probability are reported for the one-year horizon.

figure shows a clear negative relationship: legal shocks associated with higher recovery rates are also associated with lower one-year default probabilities in third-country sovereigns with debt issued under the same legal framework.

Table 1 displays the regression results for equation (10) across the term structure of default probabilities. It reports the effect of a one-percentage-point increase in the recovery rate on the probability of default over horizons of six months, one year, and two years. I report results for two specifications: (i) a simple OLS regression that only relates the change in the term structure of default probabilities to the change in the recovery rate, and (ii) my main specification which also features sovereign fixed effects, as well as trade controls. I focus on specification (II), which absorbs time-invariant sovereign characteristics and controls for trade-based spillovers from the shock-origin country. As can be seen from table 1, results are similar across specifications, indicating that results are unlikely to be driven by trade-based macroeconomic contagion rather than the legal channel.

The estimates provide strong empirical support for the hypothesis that increases in the recovery rate induced by legal shocks reduce market-implied default probabilities. My main specification indicates that a one percentage point increase in the recovery rate decreases the probability that a sovereign will default over the next year by 0.19 percentage points. The effect is highly statistically significant. Consistent with the assumed term structure of de-

TABLE 1: EFFECT OF RECOVERY RATE ON THE DEFAULT PROBABILITY

| | Term Structure of the Default Probability | | | | | |
|---|---|---|---|---|---|---|
| | $\Delta p(0.5)$ | | $\Delta p(1)$ | | $\Delta p(2)$ | |
| | (I) | (II) | (I) | (II) | (I) | (II) |
| $\Delta RV$ | -0.11*** | -0.11*** | -0.18*** | -0.19*** | -0.33*** | -0.34*** |
| | (0.025) | (0.028) | (0.022) | (0.023) | (0.092) | (0.096) |
| Fixed Effects | NO | YES | NO | YES | NO | YES |
| Trade Controls | NO | YES | NO | YES | NO | YES |
| Adjusted $R^2$ | 0.435 | 0.412 | 0.389 | 0.380 | 0.289 | 0.289 |
| $N$ | 150 | 150 | 150 | 150 | 150 | 150 |

Note: I use two-way clustered standard errors by country and legal-shock date, which I report in parentheses. Statistical significance is indicated by *, **, and *** at the 5%, 1% and 0.1% level.

fault, the magnitude of the effect rises nonlinearly with the horizon. A one percentage point increase in the recovery rate likewise decreases the probability that a sovereign will default over the next six months (two years) by 0.11 (0.34) percentage points. Across the horizon, changes in the recovery rate around court rulings can explain roughly 30 to 40 percent of the variation in changes in default probabilities.

**Robustness Checks.** I conduct several robustness checks to assess whether the baseline estimates are driven by the parameter-estimation procedure, influential observations, the choice of event window, or coincident macro-financial shocks.

First, I examine whether the joint estimation procedure for recovery and default risk can mechanically generate a relationship between the two even in the absence of any true underlying effect. To do so, Appendix A.1 reports the results of a Monte Carlo simulation in which the estimation procedure is applied to noisy changes in bond prices that contain no structural link between recovery and default probabilities. In these simulations, no systematic relationship emerges, suggesting that the baseline estimates are not an artifact of the nonlinear estimation strategy itself. In a second simulation, I impose a link between recovery rate and default probability, which is correctly identified by the methodology.

Second, in appendix section A.2, I assess whether the results are driven by extreme observations. Excluding observations for which the change in the recovery rate exceeds 25 percentage points or the change in the default probability exceeds 5 percentage points yields slightly smaller coefficients, but the results remain qualitatively unchanged (Appendix Table 4).

Third, I verify that the results are not sensitive to the choice of event window. Appendix A.3 reports estimates using a range of alternative one- and two-day windows around each legal shock. None of these alternative windows materially changes the estimated relationship between recovery and default risk as shown in appendix table 5.

Finally, I examine whether legal-shock dates coincide with other events that could affect sovereign default expectations through channels unrelated to legal precedent. I find no overlapping major domestic macroeconomic events, central bank announcements, or coincident sovereign-litigation rulings in the countries studied. In addition, none of the relevant central banks engaged in quantitative easing or large-scale bond purchase programs before 2020 that could distort sovereign bond prices. As a further check against global financial confounding, I compare the CBOE Volatility Index (VIX) on legal-shock dates with all other days in the sample and find no statistically significant difference; if anything, average VIX is slightly lower on legal-shock dates (15.9) than on non-shock dates (16.8). Together, these checks make it less likely that the estimated effects are driven by coincident macro-financial news rather than by the legal shocks themselves.

# 3 Model

This section lays out a dynamic model which allows to study sovereign default and debt renegotiation in a small open economy. The model follows Yue (2010) in that it is a stochastic endowment economy, where the government lacks commitment, and if it defaults, it can bargain with creditors over a debt restructuring. A restructuring deal prevents the government from falling into permanent autarky, but still entails a temporary default penalty. The bargaining process takes the form of a Nash bargaining game where the threat-point is non-repayment and entering permanent autarky. I depart from Yue (2010) in that governments are not excluded from financial markets after the default until they have repaid all of their debt.

I do so to focus on the role of default penalties, which is the empirical focus of my paper. The model allows to link the unobservable change in the cost of default to the change in the default probability where I impose the previously estimated link between recovery rates and default probabilities abscent from financial exclusion.

### 3.1 Model Environment

The model features three agents: the government, households, and international creditors. The model assumes an endowment economy, where the endowment $y_t$ is stochastic and drawn from $Y = [\underline{Y}, \bar{Y}] \subset \mathbb{R}^+$. Output is assumed to evolve according to a Markov chain where the probability distribution of $y_t$ conditional on the previous $y_{t-1}$ is determined by $\mu(y_t|y_{t-1})$.

Further, the government can borrow from or lend to international creditors via one-period zero coupon bonds that repay one unit of the consumption good in the next period. I denote $B$ as the face value of the zero coupon bond. A positive $B$ denotes that the government purchases bonds and lends to the international creditors, while a negative $B$ reflects borrowing by the government. The set of bond face values from which the government can choose is $b \in \mathcal{B} = [B_{min}, B_{max}] \subset \mathbb{R}$ where $B_{min} \leq 0 \leq B_{max}$. I set $B_{min} = -\bar{Y}/r$, which is the largest debt value the government could repay. The aggregate state of the economy is characterized by $s = (B, y)$.

**The Sovereign's Problem.** The government's objective is to maximize households' expected lifetime utility. Households are identical and have preferences given by

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t), \tag{11}$$

where $\beta$ denotes the discount factor, and $c_t$ denotes household consumption in period $t$. The utility function is denoted by $u : \mathbb{R}^+ \to \mathbb{R}$ which satisfies the Inada conditions, is continuous, and is strictly increasing and concave. consumption equals the stochastic endowment net the governments financial position from its bond holdings.

The government choose its asset position and whether or not to default, taking as given the state of the economy as well as the bond price function $q(B,y)$ and the debt recovery schedule $\alpha(B,y)$. If the country is not in default and has outstanding debt $B$, the government can either honor its debt obligations or default on its outstanding debt. Denoting the value of honoring debt obligations as $v_c(B,y)$ and the value of defaulting on debt as $v_d(B,y)$, the value function of the government becomes:

$$v(B,y) \;=\; \max\left\{v_c(B,y), v_d(\alpha(B,y)B,y)\right\} \tag{12}$$

where $v_c$ is the value function if the country does not default

$$v_c(B,y) = \max_{c,B':c+q(B',y)B'=y+B} u(c) + \beta \int_Y v(B',y')d\mu(y'|y), \tag{13}$$

and $v_d(\alpha(B,y)B,y)$ is the value of default resulting in the restructured debt level $\alpha(B,y)B$

$$v_d(B,y) = \max_{c,B':c+\tilde{q}(B',y)B'=(1-\lambda)y+B} u(c) + \beta \int_Y \left[\zeta v(B',y') + (1-\zeta)v_d(B',y')\right] d\mu(y'|y), \tag{14}$$

Here, under a restructuring agreement, the government retains access to capital markets but incurs an output loss $\lambda$ that is stochastically lifted with probability $\zeta$. The government is assumed to not be able to re-negotiate a debt restructuring until the default penalty is lifted. Thus, the price for newly issued debt equals $\tilde{q}(B',y) = \zeta q(B',y) + (1-\zeta)/(1+r)$.

**The Debt Renegotiation Problem.** The debt renegotiation problem takes the form of a generalized Nash bargaining game as in Yue (2010). Under an agreement between sovereign and creditors, debt is reduced to a fraction $\alpha(B,y)$ of the outstanding debt $B$ and the government value is $v_d(\alpha(B,y)B,y)$. If there is no agreement, the government does not repay anything and enters autarky, where it indefinitely incurs a default penalty on its endowment and is excluded from financial markets:

$$v^{\text{aut}}(y) = u((1-\lambda)y) + \beta \int_Y v^{\text{aut}}(y')d\mu(y'|y) \tag{15}$$

Similar to Yue (2010), I assume that renegotiation takes place only once for one default event. This one-round bargaining assumption keeps the model tractable. For any debt recovery rate $a$, I denote the countries' surpluss in the Nash barganing by $\Delta^G(\ a \mid B, y\ )$ and the creditors' surplus in the restructuring by $\Delta^C(\ a\ |B, y\ )$:

$$\Delta^G(\ a \mid B, y\ ) \ = v_d(aB, y) - v^{\text{aut}}(y) \tag{16}$$

$$\Delta^C(\ a\ |B, y\ ) \ = \ -\frac{aB}{1+r} \tag{17}$$

Here, the government surplus reflects the rise in utility from restructuring to $aB$ over falling into indefinite autarky. The surplus of the creditors reflects the market value of the share of debt they recover under the restructuring agreement, relative to not recouping anything.

Given debt $B$ and endowment $y$, the debt recovery rate $\alpha(B, y)$ solves the following barganing problem:

$$\alpha(B, y) = \arg\max_{a \in [0,1]} \left[ \left(\Delta^G(a \mid B, y)\right)^{\theta} \left(\Delta^C(a \mid B, y)\right)^{1-\theta} \right] \tag{18}$$

$$\text{s.t.} \quad \Delta^G(a \mid B, y) \geq 0,$$

$$\Delta^C(a \mid B, y) \geq 0$$

Here, $\theta$ denotes the sovereign's bargaining power while the creditors's bargaining power is equals $(1-\theta)$. The parameter $\theta$ captures institutional arrangements of debt renegotiation. To ensure that the problem is well defined, we impose the bargaining power set $\Theta \subset [0, 1]$ such that for $\theta \in \Theta$, the renegotiation surplus has a unique optimum for any debt position $B$ and endowment shock $y$.

**Foreign Investor Problem.** Taking the bond price function as given, the investor chooses the amount of debt $B'$ to maximize their expected profits. Because we assume the market for new sovereign debt to be completely competitive, the investors profit in equilibrium is zero and the price function becomes:

$$q(B', y) = \begin{cases} \frac{1}{1+r} & \text{if } B' \geq 0 \\ \frac{1-\delta(B',y)}{1+r} + \frac{\delta(B',y)\times\gamma(B',y)}{1+r} & \text{if } B' < 0 \end{cases} \tag{19}$$

where $\delta(B', y)$ is the default probability for the government given current endowment shock $y$ and chosen next period's debt $B'$. $\gamma(B', y)$ is the expected recovery rate next period.

We define the default set $D$ such that

$$D(B) = \{y \in Y \mid v_c(B, y) \leq v_d(\alpha(B, y)B, y)\} \tag{20}$$

We can then define the default probability as

$$\delta(B', y) \;=\; \int_{D^*(B')} d\mu(y'|y) \tag{21}$$

We define the expected recovery rate $\gamma(B', y)$ as

$$\gamma(B', y) = \frac{\int_{D^*(b')} \frac{\alpha^*(B',y')}{1+r} d\mu(y'|y)}{\int_{D^*(B')} d\mu(y'|y)} \tag{22}$$

**Recursive Equilibrium.**

**Definition 1.** A recursive equilibrium is a set of functions for (i) country's value function $v^*(B, y)$, asset holdings $B'(B, y)$, default set $D^*(B)$, consumption $c^*(B, y)$, (ii) recovery rate $\alpha^*(B, y)$, and (iii) pricing function $q^*(B', y)$ such that

1. Given the bond price function $q(B', y)$ and debt recovery rate $\alpha(B, y)$, the value function $v(B, y)$, debt policy $B'(B, y)$, consumption $c^*(B, y)$ and default sets $D^*(B)$ satisfy the countries optimization problems (12), (13), and (14).

2. Given the bond price function $q^*(B', y)$ and value function $v^*(B, y)$, the recovery rate $\alpha^*(B, y)$ solves the debt renegotiation problem (18).

3. Given the recovery rate $\alpha^*(B, y)$, the bond price function $q^*(B', y)$ satisfies the zero expected profit condition for foreign investors (19), where the default probability $\delta(B', y)$ and expected recovery rate $\gamma^*(B', y)$ are consistent with the countries default policy and renegotiation agreement.

The model setting allows us to draw general conclusions about the relationship between the default penalty, the recovery rate, and the default probability which are outlined in proposition 1 and 2.

**Proposition 1.** *In partial equilibrium with a fixed recovery rate denoted by $a$, the default set $D(B)$ is monotonically decreasing in $a$.*

$$D\left(B \mid a^H\right) \subset D\left(B \mid a^L\right) \tag{23}$$

*Proof.* For $a^L < a^H$, $\forall y \in Y, v_c(B, y) \leq v_d(a^H B, y) \Rightarrow v_c(B, y) \leq v_d(a^L B, y)$ since $v_d$ is strictly decreasing in its first argument. □

Proposition 1 shows that the model-implied partial equilibrium link between the recovery rate and the default probability coincides with the empirical findings presented in section 2. Since $D(B \mid a^H) \subset D(B \mid a^L)$, the probability of default rises as the recovery rate falls.

**Proposition 2.** *Under a constant endowment shock $\bar{y}$ and linear household utility in consumption, the recovery rate is a linearly increasing function in the default penalty for $\alpha \in (0, 1)$:*

$$\frac{\partial \alpha(B, y \mid \lambda)}{\partial \lambda} = \mathcal{M} \geq 0 \tag{24}$$

*For a constant $\mathcal{M}$.*

*Proof.* See Appendix section C □

Proposition 2 shows that under some simplifying assumptions it can be shown that the recovery rate is a linearly increasing function in the default probability. So the higher the default probability, the higher the recovery rate, as argued in section 2, when taking the recovery rate as a directionally equivalent proxy for the underlying movements in the default penalty.

### 3.2 Quantitative Analysis

In this section, I calibrate the model to analyze quantitatively the link between the default penalty and market-based default expectations.

**Calibration.** I choose an annual frequency for the calibration. Utility exhibits Constant Relative Risk Aversion (CRRA) according to:

$$u(c) = \frac{c^{1-\sigma}}{1-\sigma}. \tag{25}$$

Here, $\sigma$ is the coefficient of risk aversion. I set $\sigma$ to 2, which is standard in the macro-literature (Yue, 2010; Arellano, 2008). I further set the risk-free rate $r$ to 1.78% which equals the average daily US 5-year bond yield between 2000 and 2020.

I chose Argentina as a representative Low- and Middle-Income Country (LMIC) exhibiting default risk to calibrate my model economy to. The endowment process is estimated from a series of Argentina's GDP following Arellano (2008). It is assumed to be a log-normal AR(1) process, $\log(y_t) = \rho \log(y_{t-1}) + \varepsilon_t^y$ with $E[\varepsilon^y] = 0$ and $E[(\varepsilon^y)^2] = \eta_y^2$. The estimated values are $\rho = 0.945$ and $\eta = 0.025$. I discretize the shock into a 30-state Markov-Chain using the Tauchen method (Tauchen and Hussey, 1991).

The literature suggests sizeable but heterogeneous output losses from sovereign default. Quantitative models typically assume or estimate default penalties of around 5–12 percent (Cole and Kehoe, 1996; Mendoza and Yue, 2012; Sosa-Padilla, 2018), while empirical estimates vary more widely because default is endogenous to output contractions. Existing studies find effects ranging from small short-term losses of 0.6–2.5 percent (Borensztein and Panizza, 2009) to persistent output declines of roughly 4–10 percent (Sturzenegger, 2002; Furceri and Zdzienicka, 2012), with some recent evidence pointing to losses peaking near 3.7 percent after

TABLE 2: CALIBRATION

| Parameter | Value | |
|---|---|---|
| Risk Aversion | $\sigma = 2$ | Standard |
| Risk-Free interest Rate | $r = 1.78\%$ | Average US 5-year bond yield between 2000 and 2020 |
| Output loss in default | $\lambda = 0.05$ | (see e.g. Cole and Kehoe (1996)) |
| Stochastic Process | $\rho = 0.945, \eta = 0.025$ | Argentina's GDP |
| End of Penalty | $\zeta = 0.2$ | Match 5 year effect on output loss Kuvshinov and Zimmermann (2019) |
| **Calibration** | | |
| Time Discount Factor | $\beta = 0.646$ | 2% default probability |
| Barganing power | $\theta = 0.802$ | 27% debt recovery rate (Sturzenegger and Zettelmeyer, 2008) |

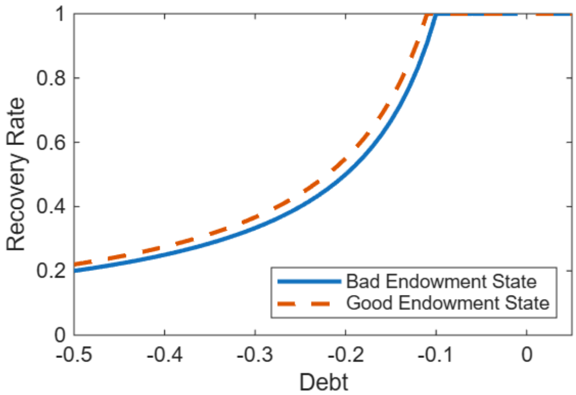
five years (Kuvshinov and Zimmermann, 2019). I choose to study comparative statics of my model for a default penalty around five percent. In line with Kuvshinov and Zimmermann (2019), I set the probability that the default penalty gets lifted after a restructuring at 20% to match an expected duration of the default penalty of five years.

Lastly, I calibrate $\theta$ and $\beta$ such that I can match two moments in my data: (i) the recovery rate of Argentina estimated in Sturzenegger and Zettelmeyer (2008), as well as (ii) an expected default probability of two percent in line with the observed default frequency in my sample of countries studied in section 2. Table 2 summarizes the parameter estimates.

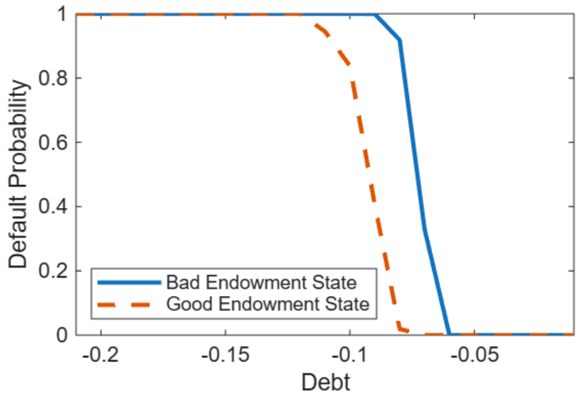
**Simulation Results** In this section, I first evaluate policy functions for selected points on the state-space, before comparing its quantitative performance in comparison with the association between the recovery rate and the default penalty identified in section 2 and what implications this has for the link between the default penalty and default probabilities under the model.

I solve the recursive competitive equilibrium laid out in definition 1, using a value function iteration algorithm. The algorithm is described in detail in appendix section E. Figure 4a plots the equilibrium debt recovery schedule over the support of assets $B$, which is reported as a ratio of average output, for two income shocks: one that is ten percent below, and one that is ten percent above the average endowment state. It plots policy functions for a moderate default penalty of five percent. Similar to insights in Yue (2010), as the amount of defaulted

FIGURE 4: EFFECT OF DEFAULT COSTS ON THE RECOVERY RATE




(A) RECOVERY RATE




(B) DEFAULT PROBABILITY

debt increases, the recovery rate decreases. Similarly, the recovery rate is higher under a good economic shock, which is in line with cross-country evidence showing that haircuts are larger if the economic fundamentals are weak at the time of default Benjamin and Wright (2009).

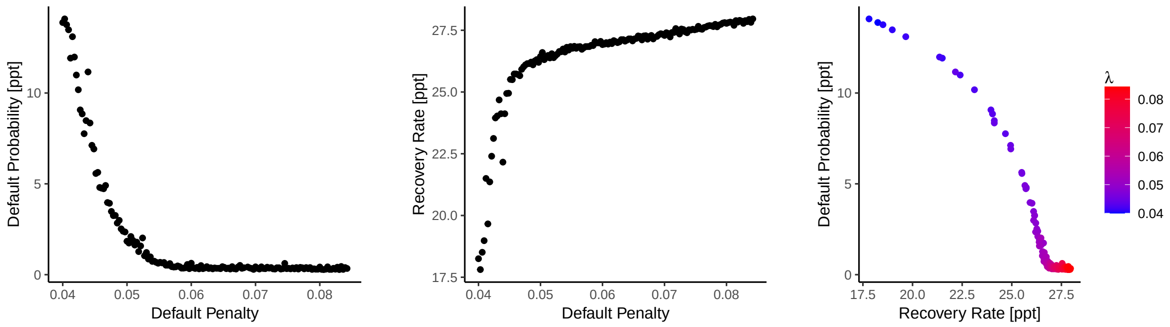
For the same two shocks and the same level of the default penalty, figure 4b plots the default probability. If debt is low, the default probability is virtually zero across all endowment shocks. Also the default probability appears to be decreasing in the endowment shock as the default is more valuable for a country facing a bad shock.

Based on the policy functions, I now simulate the economy to derive ergodic distributions over expected default probabilities, and recovery rates in the economy. I also derive comparative statics for this over a varying default penalty. Namely, I estimate the sovereign's policy functions for the government and simulate an endowment- and asset process for the respective economy with 500,000 periods in each simulation.[7] Figure 5 summarizes how the average default probability and the debt recovery schedule vary with the economic cost of default and how changes in the two induced by a changing cost of default are associated.

Figure 5a shows how the default probability varies with the cost of default. One can see that the default probability under the model is a non-linearly decreasing function in the cost of default. The higher the economic cost of default, the lower the probability that the

[7] I omit the first 50,000 observations

FIGURE 5: COMPARATIVE STATICS

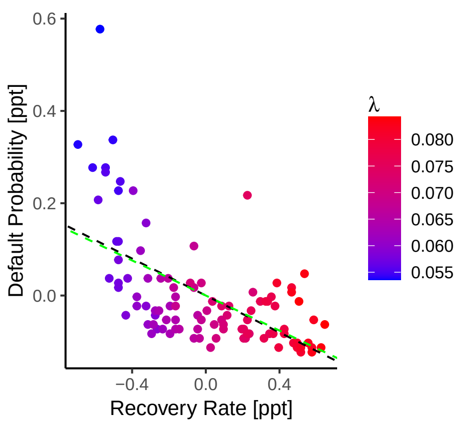



(A) DEFAULT PROBABILITY (B) RECOVERY RATE (C) RELATIONSHIP

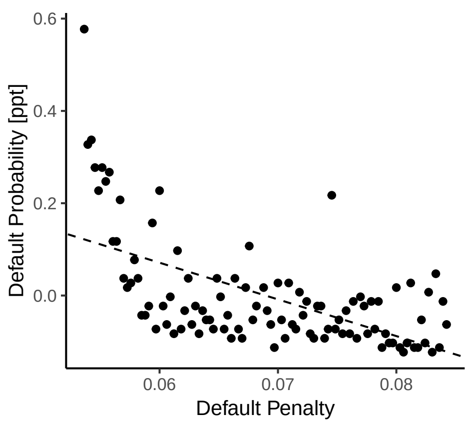
economy experiences a default event. Figure 5b shows that the recovery rate is a monotonically increasing function in the economic cost of default. As the cost of default rises, the sovereign's surplus from a restructuring deal also rises, which in equilibrium leads to higher expected recovery rates that creditors recoup under the Nash Bargaining framework. Lastly, figure 5c plots the relationship between the equilibrium default probability and the recovery rate across varying costs of default. Since the default probability is decreasing in the cost of default, and the recovery rate is increasing in the cost of default, there emerges a negative relationship between the equilibrium recovery rate and the default probability. The higher the recovery rate, the lower the default probability. This relationship is the one we estimate empirically in section 2. Given that the default probability and the recovery rate are non-linear functions in the cost of default, the relationship between the two is similarly non-linear.

Finally, this allows to study the direct link between the cost of default and the model implied default probability over a range of $\lambda$ where I can match the empirical relationship between the recovery rate and the default probability estimated from the data in section 2. Figure 6a shows model predictions for how a change in the recovery rate induced by a change in the cost of default is associated with a change in the default probability. Over a range for the cost of default between 0.055 and 0.085, I can closely replicate the empirical relationship that a one percentage point increase in the debt recovery schedule is associated with a decrease in the default probability by 0.19 percent. The black dashed line reflects the association implied

FIGURE 6: MODEL DYNAMICS




(A) MATCHED RELATIONSHIP

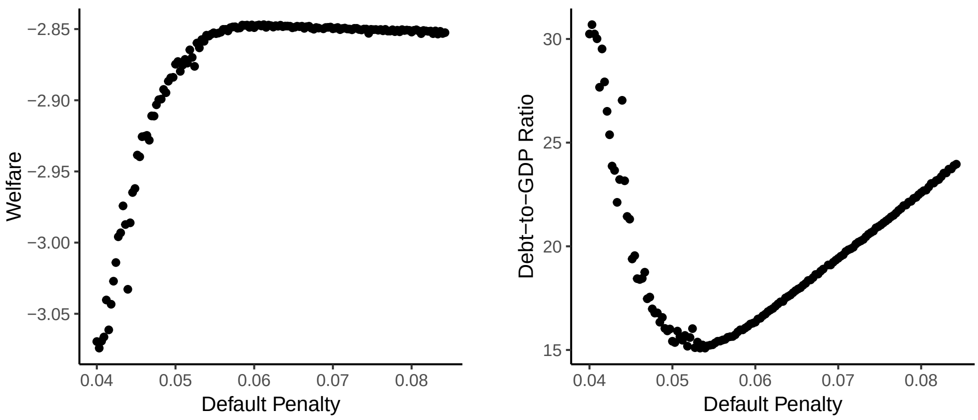



(B) MATCHED EFFECT

by the model, while the dashed green line reflects the association from my empirical findings in section 2. Now over the same range of $\lambda$, I can study the direct model implied association between a change in the economic cost of default and the default probability as shown in figure 6b. Here, I find that a one percentage point increase in the economic cost of default lowers the default probability by 7.9 basis points.

**Welfare** In addition to the default probability and the debt recovery schedule, the ergodic distribution over the state space $(B, y)$ also allows us to study how welfare and debt levels vary as the economic cost of default changes. 7a plots the expected level of the sovereign's value function over varying costs of default. Namely, I calculate the expected value of both $v(B, y)$ and $v_d(B, y)$ conditional on being subject to the default penalty or not being subject to the default penalty. As can be seen, a higher economic cost of default is welfare improving up to a point, as it functions as a device for the government that mitigates limited commitment. We can see that welfare sharply rises up until a default penalty of about 5.5, at which point the default probability drops to close to zero. Thereafter, utility is weakly decreasing in the default penalty. At the same time, we can see a U-shaped relationship between the cost of default and the equilibrium debt level that the government sustains (Figure 7b). It first falls with the cost of default, before rising again. This is driven by the fact that a higher cost of de-

FIGURE 7: WELFARE AND DEBT DYNAMICS




(A) WELFARE (B) DEBT LEVEL

fault allows for higher debt carrying capacity. More debt can be sustained without substantial default risk priced in by the markets. This opens up an interesting avenue for estimating the optimal level of the economic cost of default and whether countries are below or above this level. I leave this question for further research.

Taken together, these two facts give rise to a potential dynamic, where governments may find it optimal to issue increasingly large debt portfolios structured in a way that is increasingly economically costly to default on. Over some range of the default penalty, welfare and the debt level both increase with higher economic costs of default. While this can be optimal under the output process assumed under the model, this could give rise to high-debt-high-default-cost regimes, which make sovereigns very vulnerable to probabalistic tail events that are not correctly priced in by the sovereign. The following section 3.3 discusses this in more detail for the example of COVID-19.

## 3.3 Policy Implications

Contextually, the predictions of high-debt-high-default-cost regimes bear resemblance to recent aggregate public-, and publicly guaranteed (PPG) debt trends in Low and Middle Income Countries (LMICs), which worryingly mirror such convergence. Between 2010 and 2020, aggregate sovereign debt to GDP ratios have risen by about 44 percent (Figure 8a). At the same time, there is increasing evidence that LMIC debt has become more economically costly to restructure over the same time period across a number of dimensions (Stiglitz and Rashid, 2020, 2013). For one, LMICs' sovereign debt portfolios have become more reliant on private creditors (Figure 8a). High reliance on private creditors can expose LMICs to substantial retaliatory risks in case of a default (Stiglitz and Rashid, 2020). Further, debt obligations have become more fragmented across different geopolitical spheres of influence and groups of uncoordinated private creditors (Figure 8b). Between 2010 and 2020, the share of LMICs' debt owed to China rose from 3.9 to 10.1 percent. The share held by lenders under Western thought leadership such as the Paris Club and the World Bank fell from 38.0 to 24.5 percent. Higher fragmentation can make it increasingly difficult to strike a restructuring deal that all creditors agree to. Lastly, an increasing share of government debt is held by domestic banks, intensifying the so-called sovereign-bank nexus. Here, LMICs' bank-holdings of domestic sovereign bonds have surged over the past decade as visualized in figure 8c, accounting for more than 16 percent of the local banking sector's assets in 2020, reaching a 15-year high (IMF, 2022). This can pose severe risks around negative feedback loops between sovereign default and financial crises (Sosa-Padilla, 2018). While chiefly motivated by the experience of LMICs, the mechanism similarly applies to developed economies in which there is a risk of belief-driven crises occurring.

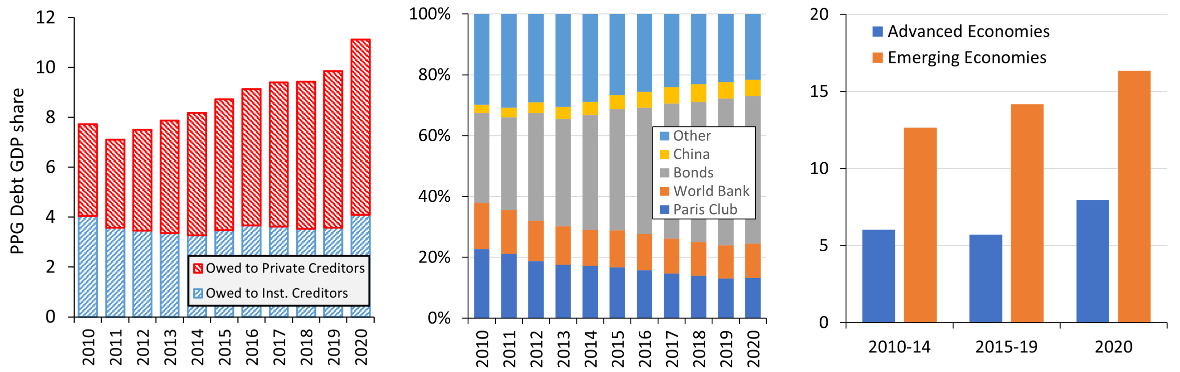
My model calibration findings relate to this co-movement. Governments may find it optimal to shift to debt portfolios that are increasingly costly to restructure, as welfare is increasing in the cost of default. Simultaneously this raises a country's debt carrying capacity and leads to larger debt levels. These trajectories qualitatively resemble the aggregate sovereign debt trajectories of LMICs throughout the decade preceding COVID-19. While being welfare improving under a normal output process, such regimes make countries very vulnerable to probabilistic tail events that may be priced incorrectly by governments. This also appeared to be the case for many LMICs, which exhibited the most muted fiscal response to COVID-19 and were among the hardest hit by the health and socioeconomic impact of the pandemic.

FIGURE 8: DEBT DEVELOPMENTS IN LOW- AND MIDDLE-INCOME COUNTRIES

(A) AGGREGATE SOVEREIGN DEBT-TO-GDP RATIOS

(B) SHARE OF AGGREGATE LMICS' DEBT BY CREDITOR

(C) PPG DEBT SHARE OF TOTAL DOMESTIC BANKING ASSETS




Source: Nominal debt data is taken from the World Bank's International Debt Statistics (IDS) 2022. Nominal GDP is taken from the World Bank's World Development Indicators (WDI) 2023. PPG debt shares of total domestic banking sector assets are taken from the IMF's April 2022 global Financial Stability Report IMF (2022).
Note: Aggregates for 123 LMICs are directly provided by the World Bank. A country is classified based on its 2021 GNI per capita. A country is low-income for a GNI below \$1,045, lower-middle-income for a GNI below \$4.095, and upper-middle-income for a GNI below \$12.695. Advanced and Emerging Economies comprise economies classified as advanced and emerging in the IMF World Economic Outlook database respectively.

Stricter regulation on creditor rights in sovereign default, and multinational regulation on the degree of risk governments can take on could help prevent a repeat of such a build-up in the future.

# 4 CONCLUSION

For several decades, one of the most important questions in international macroeconomics has been on the elusive costs of sovereign default and what role they play for default expectations as well as creditors' willingness to pay. By using an identification strategy that leverages high-frequency changes in recovery rates and default probabilities induced by legal precedent changing the interpretation of law under U.S. jurisdiction, I present novel empirical evidence in favor of the importance of default costs for curbing default expectations in sovereign bond markets. I further develop these findings in a stylized model of endogenous recovery rates and discretionary default and similarly find that rising economic costs of default lead to lower default probabilities, which can be welfare improving and lead governments to pursue high-debt-high-cost-of-default regimes. This, however, can heighten financial instability under probabilistic tail events. I show that this is akin to recent evidence from Low- and Middle Income Countries (LMICs) between 2010 and 2020 in the run-up to COVID-19. This could indicate that more regulation could prevent short-sighted governments from pursuing ex-post disadvantageous high-debt-high-default cost regimes.

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# A Empirical Robustness Checks

## A.1 Monte Carlo Simulation

In this section, I show the results of a Monte Carlo Simulation that confirms that the joint estimation procedure for the default probability and the recovery rate (Jarrow et al., 1997; Merrick, 2001) correctly identifies an underlying causal link between the two and does not mechanically generate an association, where there isn't one.

**Setup.** Let $\alpha_d$ and $\beta_d$ be the true parameters that determine the term structure of the default probability on a given date $d$ such that $\pi_d(t) = \alpha_d + \beta_d \times t$. Further, let $R_d$ be the true parameter for the recovery rate.

On two given days $d \in \{d_1, d_2\}$, with $(\alpha_d, \beta_d, R_d)$, I now simulate bond data for five imaginary bonds $i \in \{A, B, C, D, E\}$. Bonds are assumed to be issued on January 01, 2014, to mature on January 01 in the years $\{2016, 2017, 2018, 2019, 2020\}$ and to pay a biannual fixed coupon of $\{6, 7, 8, 9, 10\}$. Respectively, these assumptions uniquely pin down a series of $N^i$ coupon payments $\left(CF_n^i\right)_{n\in\{1:N^i\}}$ for each bond. Simulated bond prices of each bond on both dates then arise from the bond pricing equation 4 based on the coupon payment schedule as well as the US yield curve on the two dates. I further impose a pricing error $\varepsilon_d^{P_0}$:

$$P_d^i = \left(1 + \varepsilon_d^{P,i}\right) \times \sum_{n=1}^{N} df_n \left[ CF_n^i \times \prod_{k=1}^{n} (1 - \pi_d(t_k)) + R_d \times \prod_{k=1}^{n-1} (1 - \pi_d(t_i))\, \pi(t_n) \right] \qquad \varepsilon_d^{P,i} \sim N(0, \sigma_{Pi}^2)$$

On both days one can now back out estimates $\hat{\alpha}_d, \hat{\beta}_d, \hat{R}_d$ based on the simulated prices $\{P_d^A, ..., P_d^E\}$ based on the joint estimation methodology described in detail in section 2 (Jarrow et al., 1997; Merrick, 2001). Simulated often enough, one can compare the change in estimates to the change in the underlying parameters between the two days and validate whether the estimated change correctly captures the underlying relationship.

Now assume that the true data generating process is as follows: on both days parameters $\alpha_d, \beta_d, R_d$ fluctuate around a given parameter means $\bar{\alpha}, \bar{\beta}, \bar{R}$ and are subject to some i.i.d. noise term $\varepsilon_d^\alpha, \varepsilon_d^\beta, \varepsilon_d^R$:

$$\alpha_{d_1} = \Phi\left(\Phi^{-1}(\bar{\alpha}) + \varepsilon_{d_1}^\alpha\right) \qquad \varepsilon_{d_1}^\alpha \sim N(0, \sigma_\alpha^2)$$

$$\beta_{d_1} = \Phi\left(\Phi^{-1}(\bar{\beta}) + \varepsilon_{d_1}^\beta\right) \qquad \varepsilon_{d_1}^\beta \sim N(0, \sigma_\beta^2)$$

$$R_{d_1} = \Phi\left(\Phi^{-1}(\bar{R}) + \varepsilon_{d_1}^R\right) \qquad \varepsilon_{d_1}^R \sim N(0, \sigma_R^2)$$

On the second day, an additional shock $\varepsilon^\tau \sim N(0, \sigma_\tau^2)$ materializes which shifts $\alpha$ and $\beta$ down by $\tau\varepsilon^\tau$ and mechanically shifts $R$ up by $\varepsilon^\tau$. As the term structure of the default probability is linear in $\alpha$ and $\beta$, this implies that as the shock $\varepsilon^\tau$ raises the recovery rate by one, it lowers the default probability by $\tau$. One can think of this shock as a legal news shock that causally raises (lowers) the recovery rate and lowers (raises) the default probability, where $\hat{\zeta}$ captures the estimate from equation 10:

$$\alpha_{d_1} = \Phi\left(\Phi^{-1}(\bar{\alpha} - \tau\varepsilon^\tau) + \varepsilon_{d_1}^\alpha\right) \qquad \varepsilon_{d_1}^\alpha \sim N(0, \sigma_\alpha^2)$$

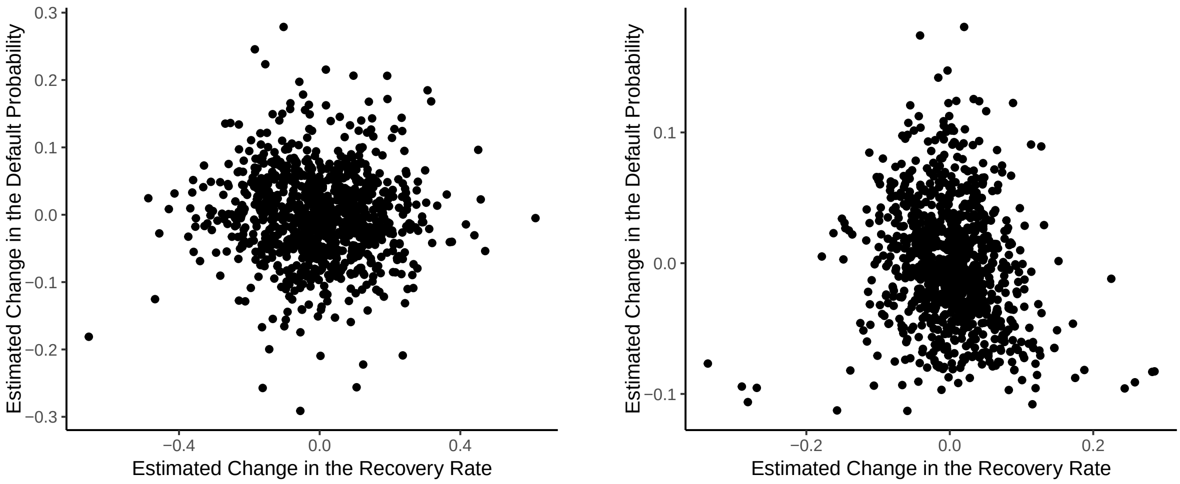
$$\beta_{d_1} = \Phi\left(\Phi^{-1}(\bar{\beta} - \tau\varepsilon^\tau) + \varepsilon_{d_1}^\beta\right) \qquad \varepsilon_{d_1}^\beta \sim N(0, \sigma_\beta^2)$$

$$R_{d_1} = \Phi\left(\Phi^{-1}(\bar{R} + \varepsilon^\tau) + \varepsilon_{d_1}^R\right) \qquad \varepsilon_{d_1}^R \sim N(0, \sigma_R^2)$$

Then, for two randomly chosen consecutive dates June 25, 2014 and June 26, 2014, I redraw 1,000 i.i.d. shocks $\{\varepsilon_{d_1}^\alpha, \varepsilon_{d_1}^\beta, \varepsilon_{d_1}^R, \varepsilon_{d_2}^\alpha, \varepsilon_{d_2}^\beta, \varepsilon_{d_2}^R, \varepsilon^\tau\}$. Denoting $k$ as the number of the draw, I then construct bond prices and estimate parameters $\hat{\alpha}_d^k, \hat{\beta}_d^k, \hat{R}_d^k$. Based on these, I further calculate $\Delta\hat{\pi}^k, \Delta\hat{R}^k$ between the two days.

**Results.** Figure 9 shows the results of two simulations. Figure 9a shows the results, where $\varepsilon^\tau \sim N(0, 0)$, meaning that there is no relationship between the changes in $R$ and $\pi$ over the two days. Under this placebo test, the estimation methodology does not find a structural relationship. Table 3 shows the regression results relating the change in estimated recovery rates and estimated changes in the default penalty and does not find a statistically significant

FIGURE 9: MONTE CARLO SIMULATION




(A) PLACEBO TEST ($\tau = 0$)

(B) CORRELATION ($\tau = 0.18$)

TABLE 3: MONTE CARLO SIMULATION

| | $\Delta p(0.5)$ | |
|---|---|---|
| | ($\tau = 0$) | ($\tau = 0.18$) |
| $\Delta RV$ | -0.01 | -0.13*** |
| | (0.014) | (0.024) |
| Fixed Effects | NO | NO |
| Trade Controls | NO | NO |
| Adjusted $R^2$ | 0.000 | 0.027 |
| $N$ | 1,000 | 1,000 |

Note: I use two-way clustered standard errors by country and legal-shock date, which I report in parentheses. Statistical significance is indicated by *, **, and *** at the 5%, 1% and 0.1% level.

relationship.

Figure 9b shows the case where $\varepsilon^\tau \sim N(0,1)$ and $\tau = 0.18$. As can be seen from the figure and regression table 3, here the joint estimation methodology correctly identifies the negative relationship underlying the two.

## A.2 Outliers

Table 4 summarizes how regression results change when excluding outlier observations for which $\Delta\pi \geq 25$ and $\Delta R \geq 5$. Estimates become quantitatively smaller, but remain qualitatively

TABLE 4: EFFECT OF RECOVERY RATE ON DEFAULT PROBABILITY

| | Robustness Check Excluding Extreme Values | | | | | |
|---|---|---|---|---|---|---|
| | $\Delta p(0.5)$ | | $\Delta p(1)$ | | $\Delta p(2)$ | |
| | (II) | (II*) | (II) | (II*) | (II) | (II*) |
| $\Delta RV$ | -0.11*** | -0.07*** | -0.19*** | -0.08** | -0.34*** | -0.11* |
| | (0.025) | (0.017) | (0.023) | (0.025) | (0.096) | (0.045) |
| Fixed Effects | YES | YES | YES | YES | YES | YES |
| Trade Controls | YES | YES | YES | YES | YES | YES |
| Adjusted $R^2$ | 0.435 | 0.167 | 0.389 | 0.337 | 0.289 | 0.365 |
| $N$ | 150 | 148 | 150 | 144 | 150 | 143 |

Note: I use two-way clustered standard errors by country and legal-shock date, which I report in parentheses. Statistical significance is indicated by *, **, and *** at the 5%, 1% and 0.1% level.

the same, retaining their negative sign and remaining statistically significant. Model II reflects regression results for all observations, while model II* reflects regression results where outliers were removed.

### A.3 Event Windows

Table 5 summarizes how regression results change when choosing a different event window. Model (II.1) reflects a one-day window between market close of the day before the court ruling and the day of the court ruling. Model (II.2) reflects another two-day window between the market close of the day before the court ruling and the day after the court ruling. Results

TABLE 5: ROBUSTNESS CHECK OVER DIFFERENT EVENT WINDOWS

| | Term Structure of the Default Probability | | | | | |
|---|---|---|---|---|---|---|
| | $\Delta p(0.5)$ | | $\Delta p(1)$ | | $\Delta p(2)$ | |
| | (II.1) | (II.2) | (II.1) | (II.2) | (II.1) | (II.2) |
| $\Delta RV$ | -0.10*** | -0.11** | -0.20*** | -0.20*** | -0.39*** | -0.38*** |
| | (0.029) | (0.033) | (0.030) | (0.046) | (0.056) | (0.083) |
| Fixed Effects | YES | YES | YES | YES | YES | YES |
| Trade Controls | YES | YES | YES | YES | YES | YES |
| Adjusted $R^2$ | 0.248 | 0.197 | 0.289 | 0.205 | 0.283 | 0.143 |
| $N$ | 150 | 150 | 150 | 150 | 150 | 150 |

Note: I use two-way clustered standard errors by country and legal-shock date, which I report in parentheses. Statistical significance is indicated by *, **, and *** at the 5%, 1% and 0.1% level.

are very similar across event windows.

## B Credit Default Swaps Around the News Shock Series.

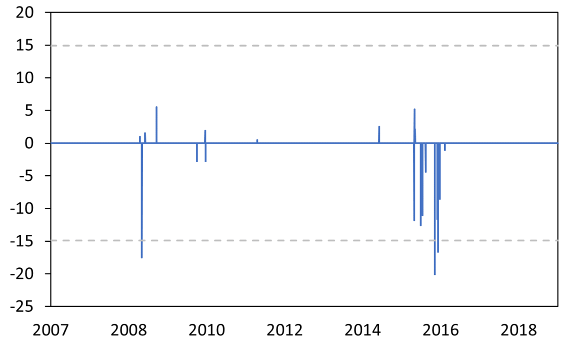
In section 2, I show that the market-implied default probability drops around court rulings that raise markets' expectations about the recovery rate. As a robustness check I now analyze changes in the Brazilian CDS spread around non-Brazilian court rulings over a longer time horizon starting in 2007. I find that the CDS spread of Brazilian bonds - a commonly used proxy for how expensive it is to insure against sovereign default - predominantly drops around the series of sovereign debt litigation outcomes compiled by Schumacher et al. (2021) that annecdotally eroded sovereign immunity and raised the cost of default. Results hold for a wide maturity-range of credit default swaps. I report findings for Brazil, since Brazil exhibits the deepest external debt markets of all countries with a history of sovereign default, indicating sufficient liquidity in CDS markets of varying maturities.

Figure (10) depicts by how many basis points (bps) the 5-year Brazilian CDS rate has changed one trading day after the court ruling compared to one day before the court ruling for the series of court rulings between 2007 and 2019. I only analyze the change around sovereign debt litigation cases under US jurisdiction, given that Brazil predominantly issues its external debt in USD.[8] I find that insurance against sovereign default has predominantly become cheaper around such court rulings. Under the assumption that the series of court rulings in Schumacher et al. (2021) predominantly set precedence for a strengthening of the plaintiffs' bargaining power in sovereign debt restructurings, a drop in Brazilian CDS rates around such rulings would indicate that a rising cost of sovereign default indeed works as a commitment device, causing a reduction in the cost of insurance for such sovereign default.

Although there is some heterogeneity among the CDS rate's reaction to court rulings, the data accords well with narrative evidence on key historical court rulings. The first big revision

[8] I take the difference in a country's CDS rate one trading day before-, and one trading day after the court ruling announcement for which CDS data for Brazil is available on investing.com: $\Delta CDS_{d,t} = CDS_{d+1,t} - CDS_{d-1,t}$. Here, $d$ indicates the trading-day of the announcement, $t$ indicates the maturity of the CDS contract, $i$ indexes the country, and $CDS^i_{d,t}$ is the CDS rate of country $i$ on a period $t$ bond at trading day $d$.

FIGURE 10: CHANGE [BPS] IN THE FIVE-YEAR CDS RATE OF BRAZIL AROUND LEGAL SHOCKS




Note: The figure shows the five-year CDS shock series for Brazilian data around US court rulings on non Brazilian debt litigation cases. The grey dashed lines reflect the 90 percent confidence bands. Confidence bands are based on variation in the day-to-day changes of the CDS rate, which exhibits a standard deviation of 9.03 bps.
Source: CDS rates are chosen from investing.com.

in Brazil's CDS rate around a court ruling occurred on the 16th of April 2009. This revision reflects the court ruling on the suit by *Montrose Capital LLC* vs. *Liberia*. This suit stands out due to the size of the amount successfully claimed by Montrose Capital LLC, which amounted to \$129.5 million: 14.7% of Liberia's nominal GDP at the time (Schumacher et al., 2021). The litigation amount of the nine court cases filed against Liberia - all ruled on at around the same time - amounted to an unprecedented 41.6% of Liberian GDP. Around the court case, the Brazilian CDS spread dropped by 17.5 bps. Further, there exists another cluster of large and negative CDS responses around various court rulings on Argentinean litigation cases in 2016, which I am also exploiting in my main analysis in section 2. These include one of the most prominent litigation cases of the recent past: *NML Capital* vs. *Argentina*. The vast majority of these shocks are negative, and two more shocks in 2016 are significant at the 10% level.[9]

Looking beyond just the 5-year CDS spreads, Table 6 summarizes key facts about the distribution of Brazilian CDS spreads of differing maturity. CDS spreads across all maturity degrees were on average negatively affected by court rulings. The effect size appears to be larger for longer CDS maturities of 3 or more years. Using a one-sample t-test, I can reject the

[9] I classify a shock as significant at the 10 percent level, if it exceeds 1.69 standard deviations of daily CDS changes.

TABLE 6: BRAZILIAN CDS RATE CHANGES [BPS] AROUND LEGAL SHOCKS

| | 6 Month | 1 Year | 2 Years | 3 Years | 4 Years | 5 Years | 10 Years | 20 Years | 30 Years |
|---|---|---|---|---|---|---|---|---|---|
| Mean | -1.87 | -2.76** | -3.65** | -4.18*** | -4.27** | -4.03** | -3.96** | -3.86** | -3.82** |
| Median | -2.18 | -1.50 | -2.49 | -1.00 | -0.96 | -0.95 | -1.08 | -0.29 | -0.69 |
| Min | -13.47 | -15.44 | -17.35 | -18.71 | -19.86 | -20.02 | -19.41 | -21.41 | -21.41 |
| Max | 11.52 | 7.47 | 6.97 | 6.73 | 6.01 | 5.54 | 5.85 | 5.72 | 6.69 |
| #Obs. | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 |

Note: *, **, *** refer to a p-value of 0.1, 0.5, 0.01 for the one-sample t-test that the sample is drawn from a standard normal distribution centered around zero. Data on CDS rates is drawn from Bloomberg, while data on court ruling dates are taken from Schumacher et al. (2021).
Source: CDS rates are taken from investing.com.

hypothesis, that these effects are drawn from a standard normal distribution centered around zero. I find a statistically significant negative effect for all CDS spreads of at least one year.

Relative to the study of the recovery rate and the default probability this approach of looking at CDS spreads has some advantages and drawbacks. The advantage of looking at CDS spreads is that this is possible over a longer time window and introduces less noise than the implicit estimation of the recovery rate and the default probability as proposed by Vrugt (2011); Merrick (2001). However, just looking at changes in the CDS spread around court rulings is insufficient to determine a causal link between an increase in the cost of default and market beliefs about default for two reasons. Firstly, although anecdotally, court outcomes from sovereign litigation cases seem to have provided mounting evidence for an increasing erosion of sovereign immunity and rising recovery rates for creditors in debt restructurings, individual court outcomes could set precedence one way or the other. They could sway bargaining power more in favor of either the creditor or the sovereign compared to the status-quo ex-ante. More careful analysis is needed to determine whether a court ruling increased or decreased the cost of future default. Secondly, even if a court ruling sets precedence for higher future recovery rates, a simultaneous drop in the CDS rate does not necessarily reflect a drop in the default probability. It could also reflect the rise in the recovery rate itself, that the insurance then does not have to cover in case of default. To address both of these concerns, I decided to primarily focus on the empirical setup proposed in section 2, yet the fact that the CDS spread drops around court rulings that annecdotally made defaulting more economically costly provides further support in favour of my findings from that section.

# C Proofs of Propositions

**Proof of Proposition 2**

*Proof.* Under a constant endowment shock and linear household utility in consumption, we can derive a the following closed-form expressions:

$$v^{\text{aut}} = \frac{1-\lambda}{1-\beta}\bar{y}$$

$$v(B) = \frac{\bar{y} - B\frac{r}{1+r}}{1-\beta}$$

$$v_d(B) = \left[(1-\lambda)\bar{y} - B\frac{r}{1+r} + \beta\theta\frac{\bar{y} - B\frac{r}{1+r}}{1-\beta}\right] / \left[1-\beta(1-\theta)\right]$$

$$\Delta^G(a \mid B) = \left[(1-\lambda)\bar{y} - aB\frac{r}{1+r} + \beta\theta\frac{\bar{y} - aB\frac{r}{1+r}}{1-\beta}\right] / \left[1-\beta(1-\theta)\right] - \frac{1-\lambda}{1-\beta}\bar{y}$$

$$\Delta^C(a \mid ) = -\frac{aB}{1+r}$$

We can summarize that the following holds

$$\Delta^G(a \mid B) = A + Ca$$

$$s.t. \quad A = \left[(1-\lambda)\bar{y} + \beta\theta\frac{\bar{y}}{1-\beta}\right] / (1-\beta(1-\theta)) - \frac{1-\lambda}{1-\beta}\bar{y}$$

$$C = \left[B\frac{r}{1+r} + \frac{\beta\theta B\frac{r}{1+r}}{1-\beta}\right] / (1-\beta(1-\theta))$$

The lagrangian for the Nash barganing is:

$$\mathcal{L} = \left(\Delta^G\right)^{\theta}\left(\Delta^C\right)^{1-\theta}$$

The FOC of the lagrangian with respect to $a$ yields

$$a = -(1-\theta)\frac{A}{C} \tag{26}$$

Now finally, we can show that $\partial a/\partial\lambda \geq 0$, meaning that a rise in the default penalty leads to a rise in the share of the recovery rate that creditors recover after a restructuring.

$$\frac{\partial a}{\partial \lambda} = \mathcal{A}\left(\frac{1}{1-\beta} - \frac{1}{1-\beta(1-\theta)}\right)\bar{y} \geq 0$$

This holds as we can show that $\mathcal{A} \geq 0$. □

# D Descriptive statistics

TABLE 7: SPATIAL AND TEMPORAL DISTRIBUTION OF LEGAL SHOCKS

(A) SPATIAL DISTRIBUTION

| Defendant | Frequency |
|---|---|
| Argentina | 30 |
| Congo | 9 |
| Liberia | 6 |
| Iraq | 5 |
| Nicaragua | 4 |
| Ecuador | 3 |
| Democratic Republic of Congo | 2 |
| Sudan | 2 |
| Guyana | 2 |
| Peru | 2 |
| Grenada | 1 |
| Zambia | 1 |
| Dominica | 1 |
| Gambia | 1 |
| Uganda | 1 |
| Niger | 1 |
| Pakistan | 1 |
| Bulgaria | 1 |

(B) TEMPORAL DISTRIBUTION

| Year | Frequency |
|---|---|
| 2000 | 7 |
| 2001 | 3 |
| 2002 | 4 |
| 2003 | 2 |
| 2004 | 2 |
| 2005 | 1 |
| 2006 | 6 |
| 2007 | 8 |
| 2008 | 4 |
| 2009 | 4 |
| 2010 | 3 |
| 2011 | 0 |
| 2012 | 5 |
| 2013 | 7 |
| 2014 | 4 |
| 2015 | 1 |
| 2016 | 11 |
| 2017 | 1 |

# E Value Function Iteration Algorithm

The equilibrium is computed as follows.

1. Discretize asset holdings $B \in \mathcal{B}$ and endowment shocks $y \in \mathcal{Y}$. The asset grid is chosen so that its bounds do not bind, and the endowment process is approximated by a finite-state Markov chain with transition matrix $\Pi$ based on the output process of Argentina.

2. Guess an initial restructuring schedule $\alpha^{(0)}(B, y)$, where $\alpha(B, y) \times B$ denotes the post-restructuring debt level.

3. Given $\alpha^{(k)}(B, y)$, solve for the equilibrium bond price schedule $q^{(k)}(B', y)$ by iterating on bond prices:

   (a) Guess an initial price schedule $q^{(k,0)}(B', y)$.

   (b) Given $q^{(k,m)}(B', y)$ and $\alpha^{(k)}(B, y)$, solve the country's dynamic programming problem by value function iteration. This delivers the repayment value $V^c$, the default value $V^d$, and the optimal borrowing policies.

   (c) Determine the default set by comparing repayment and default values:

   $$D(B, y) = \mathbf{1}\left\{V^c(B, y) \leq V^d(\alpha^{(k)}(B, y), y)\right\}.$$

   (d) Update bond prices using investors' zero-profit condition:

   $$q^{(k,m+1)}(B', y) = \frac{1}{1+r} \sum_{y'} \Pi(y'|y) \left[1 - D(B', y') + D(B', y') \frac{\alpha^{(k)}(B', y')}{B'}\right],$$

   with $q^{(k,m+1)}(B', y) = 1/(1+r)$ for $B' \geq 0$.

   (e) Repeat until the bond price schedule converges, and set $q^{(k)} = q^{(k,m+1)}$.

4. Given the converged price schedule $q^{(k)}$, solve the bargaining problem state by state to obtain an updated restructuring schedule $\alpha^{(k+1)}(B, y)$.

5. If $\alpha^{(k+1)}$ is sufficiently close to $\alpha^{(k)}$, stop. Otherwise, return to Step 3.

6. At convergence, the algorithm delivers the equilibrium price schedule $q^*$, restructuring schedule $\alpha^*$, value functions, policy functions, and default set.