Online Appendix for: Sovereign Debt Restructurings

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February 27, 2020

Appendix A Data details

A.1 Haircuts and maturity extensions

The data set of Cruces and Trebesch [2013b] contains the following three measures of haircuts in sovereign debt restructuring episodes:[1]

- "Face-value" (FV) haircut:

$$H_{FV} = 1 - \frac{\text{Face Value of New Debt}}{\text{Face Value of Old Debt}}.$$

  This is a commonly used measure that considers only the nominal value of debt, so it does not take into account the timing of payments.

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[1]For the data, see Cruces and Trebesch [2013a]. These authors make available an updated version in their website: https://sites.google.com/site/christophtrebesch/data.

- "Market value" haircut:

$$H_{MV} = 1 - \frac{\text{Present Value of New Debt}}{\text{Face Value of Old Debt}}.$$

  The expression uses the present value (PV) measure of the new debt, therefore considering the timing of payments of the new obligations. The reason to use the FV of the old debt is that, according to most common practices and regulations, all future payments become current at the time of default.

- The measure proposed by Sturzenegger and Zettelmeyer [2005],

$$H_{SZ} = 1 - \frac{\text{Present Value of New Debt}}{\text{Present Value of Old Debt}},$$

  differs from the previous measure in that the PV of the old debt is now considered.

Note that taking the ratio of the complements of H_{SZ} and H_M, we obtain

$$\frac{1 - H_M}{1 - H_{SZ}} = \frac{\text{PV of new debt}}{\text{FV of old Debt}} \times \frac{\text{PV of old debt}}{\text{PV of new Debt}} = \frac{\text{PV of old debt}}{\text{FV of old Debt}}. \tag{1}$$

In the same way, we can manipulate the ratio between the FV haircut and the MV haircut to obtain

$$\frac{1 - H_M}{1 - H_{FV}} = \frac{\text{PV of new debt}}{\text{FV of old Debt}} \times \frac{\text{FV of old debt}}{\text{FV of new Debt}} = \frac{\text{PV of new debt}}{\text{FV of new Debt}}. \tag{2}$$

The resulting expressions from these transformations are the ratio between PV and FV of the old debt (equation 1), and the same ratio for the new debt (equation 2).

To derive the expressions for the FV and the PV of debt, we consider that the debt of the country can be represented by payments d_i due over the next N years. With this notation, it is simple to compute the FV of debt as $FV = \sum_{i=1}^{N} d_i$. Before deriving the expression for the PV, it is useful to write the share of total debt paid in each period as $s_i = d_i/FV$. Then, we can represent the PV of the sovereign debt as

$$PV = FV \times \sum_{i=1}^{N} \frac{s_i}{(1+r)^i}. \tag{3}$$

To obtain a measure of maturity extensions in restructurings, the first step is to obtain the maturity of the new debt; i.e, the debt right after restructuring. Using equations (2) and (3) we obtain

$$\frac{1-H_M}{1-H_{FV}} = \sum_{i=1}^{N} \frac{s_i}{(1+r)^i}. \tag{4}$$

As debt starts being repaid in the next period, we start i at one. To make further progress with our approach, we must assume a distribution of payments over time. For the new debt, the assumption for our benchmark results is that payments are uniformly distributed over the next N periods. We make this assumption for simplicity, and because it is the same assumption we make in the model. Thus, we need to solve the next equation for the unknown N_{new},

$$\frac{1-H_M}{1-H_{FV}} = \frac{1}{N_{new}} \sum_{i=1}^{N_{new}} \frac{1}{(1+r)^i}. \tag{5}$$

A key advantage of the data Cruces and Trebesch [2013a] is that it also contains the underlying discount rate used to value future cash flows. Thus, we have the necessary information to recover N_{new}.

The second step is to recover the maturity of the old debt; i.e, the debt defaulted upon. Using equations (1) and (3) we obtain

$$\frac{1-H_M}{1-H_{SZ}} = \sum_{i=0}^{\bar{N}_{old}} \frac{s_i}{(1+r)^i}. \tag{6}$$

In this expression, i starts at 0 because there may be debt due at the time of restructuring, when Sturzenegger and Zettelmeyer [2005] compute the present value of the defaulted debt. The uniform debt payments schedule when not in default implies that, at the time of restructuring, there are as many years of payments due as number of years between default and restructuring. As the length of the period is also observable, we use that information to recover the maturity of the old debt at the time of restructuring. The equation we use to solve for $\bar{N}_{old}$ is then

$$\frac{1-H_M}{1-H_{SZ}} = \frac{1}{\bar{N}_{old}} \Big(\mathrm{dur} + \sum_{i=1}^{\max\{\bar{N}_{old}-\mathrm{dur},0\}} \frac{1}{(1+r)^i}\Big), \tag{7}$$

where *dur* is the number of years in default, and the maturity of the old debt at the time of restructuring is $N_{old} = \max\{\bar{N}_{old} - \text{dur}, 0\}$. Our preferred measure of maturity extension is the difference between the maturity of the old debt at the time of restructuring and the maturity of the new debt; i.e.,

$$\text{Extension} = N_{new} - N_{old}. \tag{8}$$

A.2 Remaining empirical analysis

- GDP per capita: We use the "GDP per capita (constant 2010 US$)" ("NY.GDP.PCAP.KD") from the World Development Indicators (WDI) [World Bank, 2019] provided by the World Bank. For the volatility and correlations, we HP filter the data for the entire horizon with available data.

- Consumption: For the moments on consumption, we use "Households and NPISH's Final consumption expenditure per capita (constant 2010 US$)", provided by the WDI ("NE.CON.PRVT.PC.KD"). For the volatility and correlations, the paper follows the same approach as for the GDP per capita, by HP filtering the log consumption per capita for the entire period. We also use this variable to construct the trade balance by subtracting consumption from output.

- Maturity: For Colombia the data is from "Ministerio de Hacienda y Credito Publico" and for Brazil is from "Secretaria de Tesouro Nacioal". These data are reported monthly and we take the median across months within each year. For Chile (1999-2010) and Mexico (2007-2010) we use "Average term to maturity for foreign debt" from OECD [2019], in their Finance/Central Government Debt Category.

- Duration: For the duration of debt for Colombia we use data from "Ministerio de Hacienda y Credito Publico", as we do for the maturity for this country. This measure of duration follows the Macaulay definition, as we use for our computations in the model. For Brazil and Mexico, we compute the duration using the maturity data described above for these countries (call m), together with the "Average interest on new external debt commitments, official (%)" provided by the International Debt Statistics ("DT.INR.OFFT", call r_o). In particular, we use the following equation to compute the Macaulay measure of duration for these two countries:

$$\text{Duration} = \frac{\sum_{t=1}^{m} t \times \left(\frac{1}{1+r_o}\right)^t}{\sum_{t=1}^{m} \left(\frac{1}{1+r_o}\right)^t}.$$

For Chile, we directly use the "Duration Macaulay of foreign debt" from the OECD database given the sufficient availability.

- Spreads: In order to construct the bond yield spreads, we obtain monthly Brazil, Colombia and Mexico zero coupon one and ten year U.S. dollar sovereign yields obtained from the Bloomberg database [Bloomberg L.P., 2019]. In particular, we use USD Brazil Sovereign (FMC 802) Zero coupon one year yield ("F80201Y"), and ten year yield ("F80210Y Index"); USD Mexico Sovereign (FMC 804) Zero coupon one year yield ("F80201Y") and ten year yield ("F80210Y"); USD Colombia Sovereign (FMC 803) Zero coupon one year yield ("F80201Y"), and ten year yield ("F80210Y").

  For Chile, we use mid-yield to maturity for one and ten years also from the Bloomberg database. The specific indices are "I257 USD Chile Sovereign Curve 1Y(CHILE 3 7/8 08/05/20) (Mid YTM)" and "I257 USD Chile Sovereign Curve 10Y(CHILE 3.24 02/06/28) (Mid YTM)".

  We aggregate monthly yields into yearly by taking the median within each year. The yield spreads are obtained by subtracting one- and ten-year US Treasury constant maturity rates provided in the FRED database. The indices are "DGS1" and "DGS10", respectively.

All the replication material to compute empirical moments are in the AEA Data and Code Repository for this paper. See Dvorkin et al. [2019]. The readme file contains more detailed data information and links to data sources for online access.

Appendix B Computational Details

B.1 Basics

We solve the model numerically with value function iteration on a discretized grid for debt and output. For each maturity m_i, we use a different debt grid, evenly spaced between 0 and $0.7q^*(m_i, r^R)$, where $q^*(m_i, r^R)$ is the risk-free price for a bond of maturity m_i. We use 121 points for the debt grid, and 51 points for the output grid. We solve the policy and value functions for all points on these grids, and conduct a discrete search to find the optimal debt policy also over these grids. The price function is solved for 41 equally-spaced points on this grid, and the implied function is linearly interpolated in the other parts of the algorithm. As the steeper regions of the price function is where default usually happens, we have an uneven grid for income that is finer below the median income. In particular, the income grid is spread evenly both below the median income over 40 points and above the median income grid over 10 points. We use the Tauchen method to discretize the income process.

We solve for the lenders' offer, $W^L(y, b_i, m_i)$, through a discrete search over 501 points on a state-specific evenly-spaced W-grid. The lowest point on the grid is 0 and the highest is $\min[0.7, -b \times m_i]$. As the borrowers' offer $W^S(y, b_i, m_i)$ is equal to $-b_i\, q^D(y, b_i, m_i; m_i)$ it is not necessary to follow the same discrete search as W^L for W^S.

For convergence, we use a measure of distance for the price function of debt in good standing in a given iteration, that takes into account the maximum absolute distance of the prices across two iterations relative to the level of the price in a given state. We declare convergence when this error is lower than 10^{-5}. We update the lenders' offer only when this error is $< 10^{-4}$.

After solving for the policy and value functions, we run the simulations for 1500 countries (paths) for 400 years and drop the first 100 periods. The model counterparts to the empirical correlation and standard deviation statistics are averages across samples. For the first-order moments, country-specific means are taken before averaging across countries. This is consistent with our treatment of the data.

The Fortran code to replicate the results, along with all other material, can be found in the AEA Data and Code Repository. See Dvorkin et al. [2019].

B.2 Computing duration and yield to maturity

Duration. Similar to Hatchondo and Martinez [2009] and Sánchez, Sapriza, and Yurdagul [2018], we use the Macaulay definition to compute the duration of a bond as a weighted sum of future promised payments:

$$\frac{q(y,a,b_i,m_i;1)+2\times(q(y,a,b_i,m_i;2)-q(y,a,b_i,m_i;1))+...+n\times(q(y,a,b_i,m_i;m_i)-q(y,a,b_i,m_i;m_i-1))}{q(y,a,b_i,m_i;m_i)}.$$

Yield to maturity. Consider a country with income y, debt rollover shock a, and a debt portfolio with maturity m and level b. The yield for a bond with maturity n is:

$$YTM(y,a,b_i,m_i;n)\equiv\left(\frac{1}{q(y,a,b_i,m_i;n)-q(y,a,b_i,m_i;n-1)}\right)^{\frac{1}{n}}-1.$$

Then the spread for maturity m is $YTM(y,a,b_i,m_i;n)-r$.

Appendix C Calibration of Sudden Stops

For the estimation of sudden stop shocks, we use the sudden stop definition from Comelli [2015] and update the data until 2014. We run the following regression:

$$SS_{t,i}=\alpha_0+\alpha_1 SS_{t-1,i}+\alpha_2(GDP\ cycle)t,i+\alpha_3(demean\ Debt/GDP)_{t,i}, \quad (9)$$

where SS is a dummy variable that is 1 if there is a sudden stop and 0 otherwise. Given that our model already captures fluctuations in credit availability due to income and indebtedness, we want to capture sudden stops when income and debt are in normal levels. Given that the variables $(GDP\ cycle)$ and $(demean\ Debt/GDP)$ have mean zero, we can obtain $\omega^N=\alpha_0$ and $\omega^{SS}=\alpha_0+\alpha_1$. The results are shown in Table 1.

To make sure our episodes are not fluctuations in the availability of credit related to the country's income and indebtedness, which are endogenous in our model, in the next figure we plot the share of the countries in sudden stop for each year. The figure shows that there is bunching of sudden stops, suggesting that these episodes are due to changes external to the country .

Appendix D ϵ-zero model

Consider a case with debt level $-b_i$, maturity m_i, income y, not experiencing a rollover shock, whose observed decision is to not default, and take a

Table 1: Estimation of sudden stop probability

Regression type	Weight	Obs	R^2	ω^N	ω^{SS}
Linear reg., controlling by HP cycle and debt-to-GDP	No	457	0.1	0.11	0.42
Linear reg., controlling only by HP cycle	No	971	0.09	0.14	0.44
Linear reg., controlling by HP cycle and debt-to-GDP	Yes	457	0.1	0.11	0.4
Linear reg., controlling only by HP cycle	Yes	971	0.12	0.13	0.44
Probit reg., controlling by HP cycle and debt-to-GDP	No	457	0.1	0.11	0.41
Probit reg., controlling only by HP cycle	No	971	0.08	0.14	0.43
Probit reg., controlling by HP cycle and debt-to-GDP	Yes	457	0.09	0.11	0.39
Probit reg., controlling only by HP cycle	Yes	971	0.11	0.13	0.43
Average of all specifications			0.10	0.12	0.42

Note: In the regressions with weights we use employment for the Penn World Table [Feenstra et al., 2015] as a proxy for the size of the country.

portfolio with $-b'_j$ and m'_j to the next period. In this case, the value of not defaulting with a realization $\boldsymbol{\epsilon}$ equal to zero is

$$\hat{V}^P(y,0,b_i,m_i) = \max_{b_j,m_j} \left\{ u(c_{ij}(y)) + \beta E_{y',a'|y,0} E_{\boldsymbol{\epsilon}'} V^G(y',a',b_j,m_j,\boldsymbol{\epsilon}') \right\}$$

subject to

$$c_{ij}(y) = y + b_i + q(y,0,b_j,m_j;m_i-1)b - q(y,0,b_j,m_j;m_j)b_j \text{ and } j \in \{1,2,...,\mathcal{J}\}.$$

From this problem we obtain the policy functions of the $\boldsymbol{\epsilon}$-zero model.

If the economy is experiencing a rollover shock, the value of repayment with $\epsilon_i = 0$ is

$$\hat{V}^P(y,1,b_i,m_i) = u(y+b_i) + \beta E_{y',a'|y,1} E_{\boldsymbol{\epsilon}'} V^G(y',a',b_j,m_j,\boldsymbol{\epsilon}').$$

Similarly, the value of defaulting with $\epsilon_{\mathcal{J}+1} = 0$ in the current period would have been:

$$\hat{V}^D(y,b_i,m_i) = u(y) + \beta E_{y'|y} E_{\boldsymbol{\epsilon}'} V^R(\min\{y',\pi^R\},b_i,m_i,\boldsymbol{\epsilon}'),$$

From here we obtain the policy function of default for the $\boldsymbol{\epsilon}$-zero model. In particular, the country defaults if $\hat{V}^P(y,0,b_i,m_i) \leq \hat{V}^D(y,b_i,m_i)$.

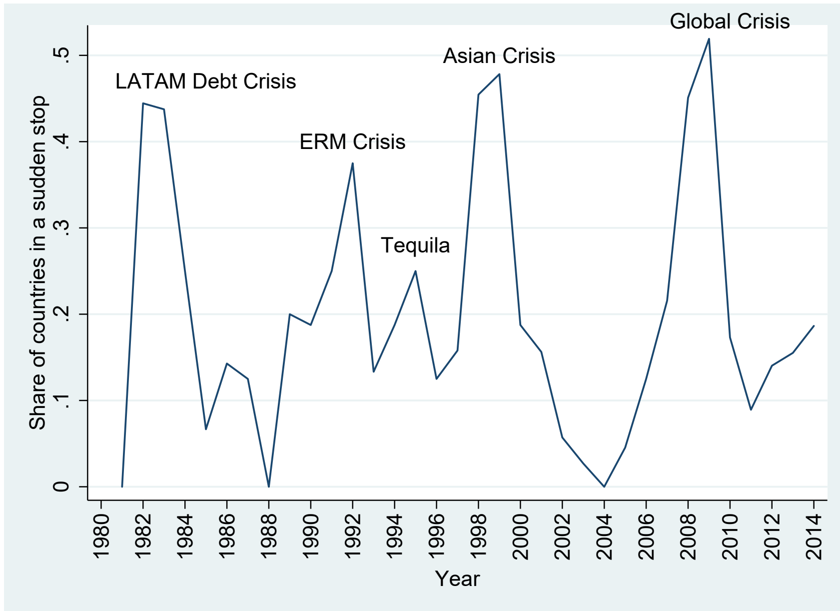

Figure 1: Bunching of Sudden Stop events

Appendix E Sudden stop shocks: sensitivity analysis

In this Appendix we evaluate the robustness of our results to changes in the sudden stop assumption.

In Table 2, Panel A can be compared to the statistics reported in the bottom section of Table 5 in the paper. Similarly, Panel B shows the moments reported in Table 6 of the article, and Panel C relates to the last row of Table 8 in the paper. The first column of results in this table shows the benchmark calibration of the article, and the second column illustrates the results with the same calibration but no sudden stops.

The comparative results in Table 2 highlight that while sudden stop shocks do matter for the level of some statistics in the model, they do not drive our key finding on maturity extensions in restructurings. Absent sudden stop shocks, Panel A shows the debt-to-output ratio and the length of default remain unchanged, the default rate becomes slightly lower, and the mean haircut and the volatility of debt decrease. Panel B illustrates that the economy experiences a lower level of debt maturity and duration, where,

Table 2: Robustness check: Targeted and untargeted moments

	Benchmark calibration	Economy with no Sudden Stops
Panel A: Targeted moments		
Debt / Output	31.74	30.23
Default rate	2.35	1.84
Length of default (years)	2.32	2.36
Mean SZ haircut	34.05	24.39
Average issuance costs	1.10	0.71
Std. dev. duration	0.89	0.44
Std. dev. debt/output	9.47	5.52
Panel B: Non-targeted moments		
St. dev. (log(c))/St. dev. (log(y))	1.17	1.13
St. dev. (TB/y)/St. dev. (log(y))	0.63	0.45
Corr. (log(c), log(y))	0.84	0.91
Corr. (TB/y, log(y))	0.04	-0.06
Duration (years)	3.43	2.04
Duration (years, bad times)	3.05	1.97
Maturity (years)	6.20	3.16
Maturity (years, bad times)	5.43	3.04
Corr. (maturity,log(y)	0.38	0.16
Corr. (duration,log(y))	0.47	0.22
1-year spread (%)	0.77	0.56
1-year spread (%, bad times)	1.53	1.11
10-year spread (%)	1.01	0.60
10-year spread (%, bad times)	1.37	0.84
Corr. (1YS, log(y))	-0.22	-0.34
Corr. (10YS, log(y))	-0.55	-0.69
10YS – 1YS(%)	0.24	0.04
Panel C: Extensions		
Maturity extension (years)	4.32	5.39

for instance, the average maturity decreases from an average of 6.20 years to 3.16 years. Sudden stops are an essential force that generates a higher level of maturity in line with the data. More importantly, as Panel C shows, the average maturity extension upon restructuring in the benchmark setup is somewhat lower than in the absence of sudden stops. Thus, we find that the presence of sudden stops does not drive the result of maturity extensions in the model.

In Table 3, Panel A replicates Table 10 in the paper, where we assess the role of the income recovery between default and restructuring on the debt restructuring generated by the model. For comparison purposes, in Panel B we report the same moments for an economy with the same calibrated parameters but without sudden stops.

The differences between the moments reported in the second and third columns show that haircuts, maturity extension, and duration of default are sensitive to the economy's recovery. More importantly, these statistics do not vary across panels, indicating that the role of income recovery does not depend on sudden stop shocks.

Table 3: Robustness check: The effect of income recovery

Panel A:	Economy with Sudden Stops		
		Baseline	
	All	No recovery	Recovery
Avg. haircut, face value	27.72	32.69	23.03
Avg. haircut, SZ	34.05	37.41	30.92
Mean extension	4.32	3.84	4.78
Duration of Default	2.32	2.16	2.46
Panel B:	Economy without Sudden Stops		
	All	No recovery	Recovery
Avg. haircut, face value	12.75	21.98	9.79
Avg. haircut, SZ	24.39	29.96	22.62
Mean extension	5.39	4.57	5.65
Duration of Default	2.36	2.31	2.38

Panel A in Table 4 displays the results of Table 11 in the paper, i.e., our benchmark economy with sudden stops where we vary the exclusion probability. Panel B reports the same moments for an economy with the same calibrated parameters but without sudden stops. Similar to the pattern observed in Table 3, the results shown in Table 4 indicate that the sensitivity of the moments to changes in the exclusion parameter does not depend on sudden stop shocks. For instance, in the economy with sudden stops, the mean debt maturity extension increases by 4.2 years when δ increases from 0.12 to its benchmark value of 0.7. In the economy without sudden stops, the same change in δ is associated with a similar increase of 3.4 years. In the same way, a change in δ from 0.85 to its benchmark value induces a significant, similar increase in maturity extensions in the economies with and without sudden stops (about 6-7 years).

Table 4: Robustness check: The effect of exclusion after restructuring

Panel A:	Economy with Sudden Stops				
	Benchmark	Changes in δ			
	$\delta = 0.7$	$\delta = 0.12$	$\delta = 0.6$	$\delta = 0.75$	$\delta = 0.85$
Avg. haircut, face value	27.72	32.13	30.95	22.52	18.79
Avg. haircut, SZ	34.05	26.07	30.98	39.06	43.63
Mean extension	4.32	0.11	2.07	8.13	11.36
Duration of Default	2.32	2.52	2.35	2.27	2.21

Panel B:	Economy without Sudden Stops				
		Changes in δ			
	$\delta = 0.7$	$\delta = 0.12$	$\delta = 0.6$	$\delta = 0.75$	$\delta = 0.85$
Avg. haircut, face value	12.75	14.75	14.26	9.69	3.61
Avg. haircut, SZ	24.39	14.66	20.76	28.39	35.13
Mean extension	5.39	2.00	3.85	7.61	11.66
Duration of Default	2.36	2.58	2.38	2.36	2.27

Panel A in Table 5 replicates the findings of Table 12 in the paper, our benchmark economy with sudden stops where we vary the regulatory costs of book-value losses. Panel B reports the same moments for an economy with the same calibrated parameters but without sudden stops.

Table 5: Robustness check: The effect of regulatory costs of book-value losses

Panel A:		Economy with Sudden Stops		
	Benchmark	Alternative values of κ		
	$\kappa = 0.03$	$\kappa = 0.00$	$\kappa = 0.02$	$\kappa = 0.05$
Avg. haircut, face value	27.72	31.31	28.32	21.90
Avg. haircut, SZ	34.05	35.20	34.55	35.62
Mean extension	4.32	3.39	4.25	7.08
Duration of Default	2.32	2.28	2.30	2.33

Panel B:		Economy without Sudden Stops		
		Alternative values of κ		
	$\kappa = 0.03$	$\kappa = 0.00$	$\kappa = 0.02$	$\kappa = 0.05$
Avg. haircut, face value	12.75	14.49	12.92	9.35
Avg. haircut, SZ	24.39	24.48	24.61	23.78
Mean extension	5.39	4.90	5.40	6.21
Duration of Default	2.36	2.34	2.35	2.42

As observed in the previous tables, the sudden stop shocks help explain the levels of the moments generated by the model, but do not drive the changes in those moments when we vary the regulatory costs of book-value losses. An increase in the regulatory costs parameter from its benchmark value of 0.03 to 0.05 is associated with a rise in the mean maturity extension, which about 2.5 years in the economy with sudden stops, and about 1 year in the model economy without sudden stops.

The main conclusion from the robustness exercises described in Tables 1 through 4 is that the sudden stop shocks do not drive the main results of the paper.

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