Sovereign Debt Crises: Some Data and Some Theory

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PIER Lecture

Debt Crises

Debt Crises = government has trouble selling new debt.

Trouble selling includes

- large jump in the spread over low risk debt
- failed auction
- suspension of payments
- creditor haircuts
- outright default.

Often this means not able to rollover maturing debt.

Debt Crises

Modern literature begins with LDC debt crises of the 1980s.

- Oil price shocks lead to OPEC lending and LDC borrowing
- Rise in interest rates makes things worse.
- Economic downturns plus large debts lead to Debt Crises.

Continues up until the present, with the EU crises.

Can involve bond or bank debts;

public debt or private debt government ends up guaranteeing.

Roadmap

- Start with some data
- Examine our models' ability to account for this data.
- Find some problems and suggest a modified road.

Talk based recent work with Mark Aguiar, Satyajit Chatterjee and Zachary Stangebye.

- "Quantitative Models of Sovereign Debt Crises" for Handbook of Macroeconomics
- "Belief Regimes, Risk Premia and Sovereign Debt Crises", new paper.
- "Self-Fulfilling Debt Crises Revisited: The Art of the Desperate Deal" new paper.

Pooled EMBI Spread Data from EM countries
1993Q4 - 2014Q4

Argentina	Brazil	Bulgaria
Chile	Colombia	Estonia
Hungary	India	Indonesia
Latvia	Lithuania	Malaysia
Mexico	Peru	Philippines
Poland	Romania	Russia
South Africa	Thailand	Turkey
Ukraine	Venezuela	

Defaults and Spreads

Our sample includes only two actual defaults -

- Russia in 1998
- Argentina in 2001

Includes some major crises: ex. Mexico's tequila crisis of 1994-5.

Spreads are high - mean = 431 basis points

Spreads are volatile - s.d. = 676

Define a crises to 95 percentile rise = 158 basis points.

- Some countries have no crises,
- while Argentina is in "crisis" 20 percent of the time.

Spreads include Large Risk Premia

Table: Realized Bond Returns

Period	EMBI+	2-Year Treasury	5-Year Treasury
1993Q1–2014Q4	9.7	3.7	4.7
1993Q1–2003Q4	11.1	5.4	6.3
2004Q1–2014Q4	8.2	2.0	3.1

Realized risk premium roughly on the order of the equity premium.

Seems to be some time variation in premium.

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- Argentina in 2001

and some well known crises: ex. Mexico's tequila crisis of 1994-5.

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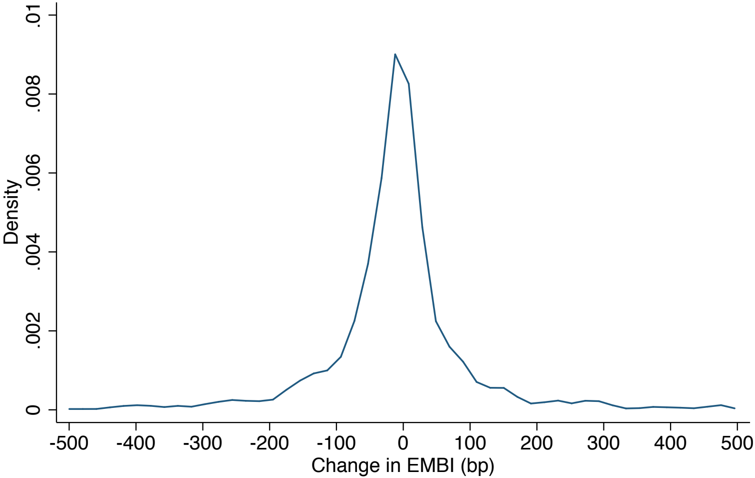
Distribution of Changes in Spreads



Truncated at −500 and 500

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What Drives Spreads?

Traditional approach to sovereign debt crises emphasizes negative shocks to output and/or fiscal balance

- Many examples in the data: Natural disasters, terms-of-trade shocks, wars, banking crises, etc.
- Consistent with Eaton-Gersovitz (1981) approach and the large quantitative literature that has developed subsequently

Other shocks in data...

- The Latin American debt crisis of the 1980s driven in part by sharp rise in US interest rates
- Political transitions (Ecuador 2009, Greece now)

Let's start with the relationship between growth, D/Y and crises.

Spreads Debt and Growth

Mean for external debt-to-output $= 0.46$.

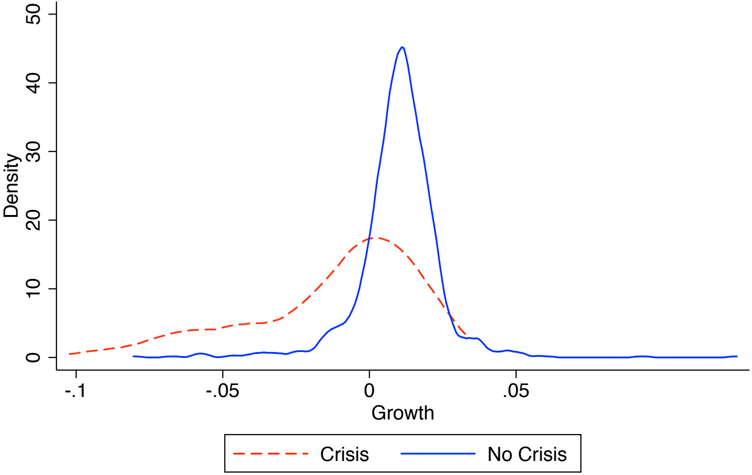
See crises at a wide range of levels of debt and growth.

Low correlation between the spread and growth rates or D/Y.

- Show some figures about growth
- Show some regression analysis.

Distribution of Contemporaneous Growth

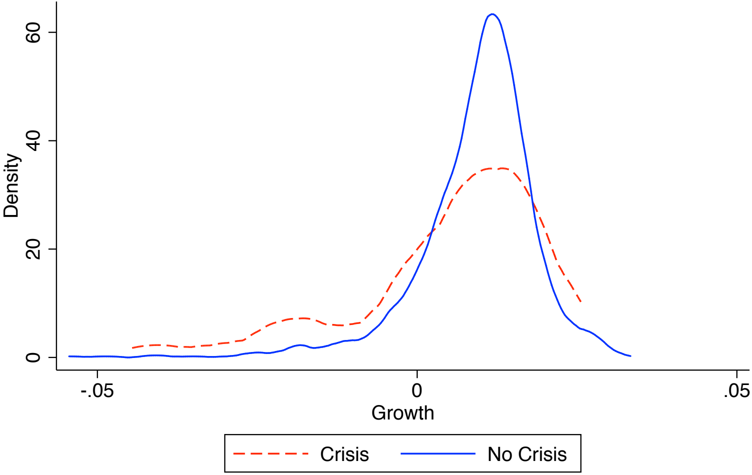
With and Without Jump in Spreads



Crisis: Contemporaneous with $\Delta EMBI > 158bp$
Median Growth: -0.4 and 1.1, resp

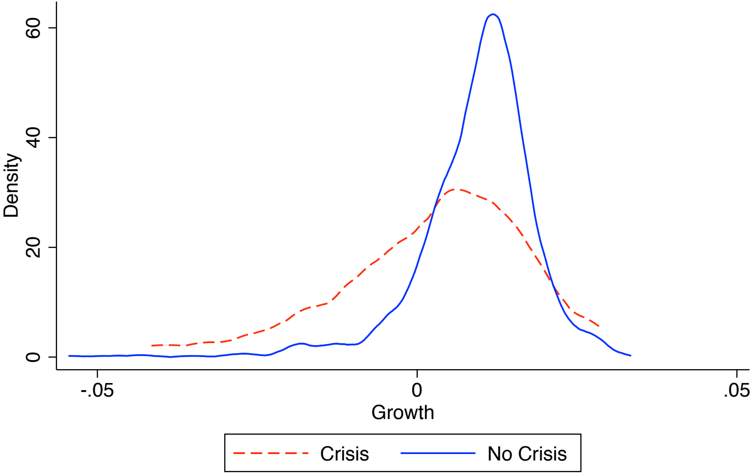
Distribution of Lagged Growth

With and Without Jump in Spreads



Distribution of Subsequent Growth

With and Without Jump in Spreads



Statistical Model of the Spreads

We specify our statistical model as follows:

$$s_{it} = \beta_i b_{it} + \gamma_i g_{it} + \sum_{j=1}^{J} \delta_i^j \alpha_t^j + \kappa_i + \epsilon_{it}, \tag{1}$$

where α_t^j is a common factor which is imposed to have a positive coefficient; $\delta_i^j \geq 0$ for all i.

Our common factors are assumed to be orthogonal and to follow AR(1) processes:

$$\alpha_t = \Gamma \alpha_{t-1} + \eta_t \tag{2}$$

Overall explanatory power is high, but fundamentals only explain a small amount typically less than 20%.

Common Factors: important, so what drives them?

Consider some key financial and interest rate variables

1. P/E ratio - the S&P500 price-earnings ratio rises when risk pricing is low.
2. VIX - measures uncertainty through an index of 30-day option-implied volatility in the S&P500 stock index.
3. LIBOR - average London inter-bank borrowing rate measures the risk-free interest rate.

Can they account for our common factors?

Common Factors ?

Table: Common Factor Regressions: Levels

Index		VIX	PE Ratio	LIBOR	R^2
			Levels		
α_t^1	Coefficient	$8.32e{-4}$	$2.00e{-3}$	$9.75e{-4}$	
		$(3.36e{-4})$	$(6.31e{-4})$	$(1.1e{-3})$	
	Var Decomp	0.10	0.17	0.02	0.29
α_t^2	Coefficient	$6.1383e{-4}$	-0.0017	0.0088	
		$(5.0460e{-4})$	$(9.4742e{-4})$	(0.0017)	
	Var Decomp	$-4.0795e{-5}$	-0.0058	0.2722	0.27

Financials partially drive 1. The risk-free rate partially drives 2.
Sign of P/E counterintuitive.

Deleveraging

How do policy makers respond to spread fluctuations?

- High and increasing spreads are often associated with subsequent reductions in debt
- $Corr(r - r^{\star}, \%\Delta B) = -0.19$ in the pooled sample

Taking Stock

Our empirical analysis has led us to a set of criteria that we would like our model to satisfy:

1. Crises, and particularly defaults, are low probability events;
2. Risk premia are an important component of sovereign spreads;
3. Spreads are highly volatile;
4. Crises are not tightly connected to poor domestic fundamentals;
5. Global financial factors and interest rates also only have limited importance.
6. Rising spreads are associated with de-leveraging by the sovereign.

Modeling Preliminaries

Sovereign debt lacks a direct enforcement mechanism. So need default costs.

Countries repay large amounts of debt, so need big physical default costs - not just reputation effects. (Mendoza and Yue 2012)

Defaults occurring because debt is not state-contingent. So, default provides a form of insurance.

But very poor insurance since costs are big and, lenders are rational and risk averse.

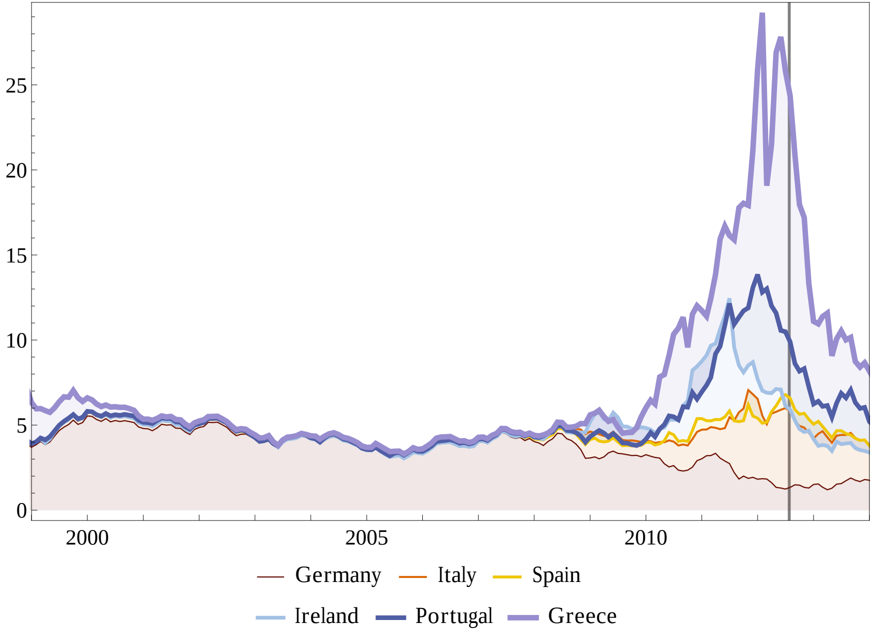
Government myopia will thus be important to induce borrowing and rule out buffer-stock savings.

But its a very delicate balance between default costs, myopia and risk pricing to match data.

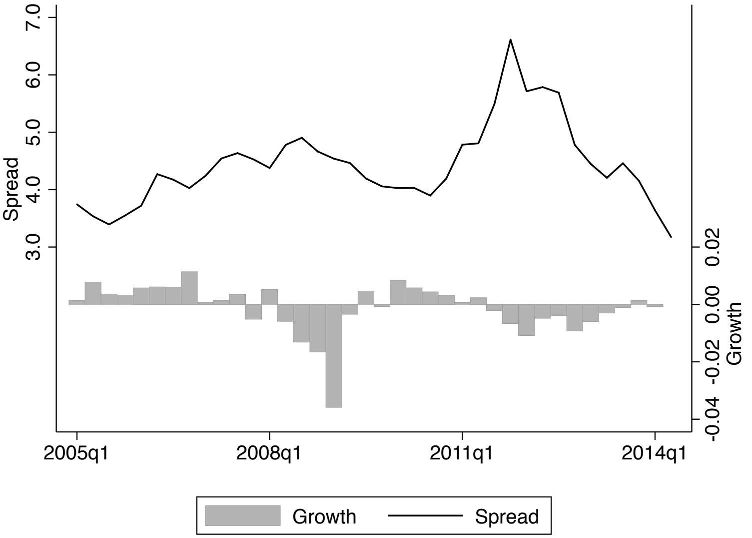
Crises without fundamental shocks...

- Debt crises often associated with only small (or no) declines in output or other fundamentals (more on this later)
- Quantitative models typically require large falls in output to trigger default (more on this later)
  - More than business cycles needed
- Self-fulfilling debt crises have been the focus of a literature that has arisen primarily in response to the European crisis
  - In the Calvo (1988) tradition: Lorenzoni-Werning, Nicolini-Teles
  - In the Cole-Kehoe (2000) tradition: Conesa-Kehoe, Aguiar-Amador-Farhi-Gopinath

Why we think beliefs matter...



Italy



Spread
7.0
6.0
5.0
4.0
3.0
0.02
0.00
-0.02
-0.04
Growth
2005q1
2008q1
2011q1
2014q1
Growth
Spread

Framework

Key Ingredients

- Markov process for endowment growth
- Shocks to lender wealth (Risk Premia)
- Default costs in the form of lost output and lost access to asset markets for stochastic period of time.
- Multiplicity of equilibria
- Markov process for beliefs

Environment

Domestic Economy

- Small open economy
- Discrete time $t = 0, 1, ...$
- Single tradable good
- Endowment process: $y_t \equiv \ln Y_t$ stochastic growth shocks following an $AR(1)$ process

Trend stationary has been focus of the literature following RBC paradigm. But stochastic growth more realistic esp. for LDCs.

Domestic Economy

Preferences

- Sovereign government makes all consumption-savings-default decisions
- Sovereign's preferences over sequence of aggregate consumption $\{C_t\}_{t=0}^{\infty}$:

$$\mathbb{E} \sum_{t=0}^{\infty} \beta^t u(C_t)$$

with

$$u(C) = \frac{C^{1-\sigma}}{1-\sigma}$$

Financial Markets

- Sovereign issues non-contingent "random-maturity" bonds
- Bonds mature with Poisson probability λ
- Assume that in a non-degenerate portfolio of bonds, a fraction λ matures with probability 1
- Perpetual-youth bonds allow for tractably incorporating maturity without adding separate state variables for each cohort of bond issuances

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- Bonds pay coupon r^* each period up to and including maturity
- Payments due in period t: $(r^* + \lambda)B_t$
- New issuances: $B_{t+1} - (1 - \lambda)B_t$

Lenders

- Risk averse lenders
- Financial markets are segmented: Only a fraction of potential investors participate in bond market at a point in time
- Tractability: Period t's set of investors hold bonds for one period and then sell them to a new cohort of investors at start of $t + 1$
- Let W_t denote aggregate wealth of period-t new participants. We can allow this to evolve stochastically to generate exogenous fluctuations in risk premia

Timing

- At start of current period:
  - New lenders purchase non-maturing bonds from old lenders at auction
  - New lenders purchase new bonds from government at same auction
- Any money government raises goes into the settlement fund
- At settlement, government decides to pay maturing bonds and coupon
- If defaults, any money in settlement fund gets paid out in proportion to face value of claims

Some Useful Notation

- Normalize debt relative to output

$$b_t \equiv \frac{B_t}{Y_t}$$
$$b'_t \equiv \frac{B_{t+1}}{Y_t}$$

- Evolution:

$$b_{t+1} = b'_t \frac{Y_t}{Y_{t+1}}$$

Value Functions

- $V(s)$ denotes start-of-period value of government
- $V^R(s, b')$ denotes value if having auctioned $b' - (1-\lambda)b$ the government decides to repay $(r^* + \lambda)b$ at settlement
- $V^D(s)$ denotes the value of defaulting at settlement (independent of amount auctioned) $\Rightarrow$ lose fraction $\phi(s)$ of endowment until "redemption" from default status

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- Strategic default implies:

$$V(s) = \max \left\langle \max_{b' \leq \bar{b}} V^R(s, b'), V^D(s) \right\rangle$$

Bellman Equations

- If repay...

$$V^R(s, b') = u(C) + \beta \mathbb{E}\left[V(s')|s, b'\right],$$

with

$$\begin{aligned} C &= Y + q(s, b')(B' - (1-\lambda)B) - (r^* + \lambda)B \\ &= Y\left[1 + q(s, b')(b' - (1-\lambda)b) - (r^* + \lambda)b\right]. \end{aligned}$$

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- If default...

$$V^D(s) = u(C) + \beta(1-\xi)\mathbb{E}\left[V^D(s')|s\right] + \beta\xi\mathbb{E}\left[V(s')|s, b' = 0\right],$$

with

$$C = (1 - \phi(s))Y$$

Equilibrium

- States $s \in S$ elements of s are:
  - Endowment: (Y, g, z)
  - Bonds: b
  - Normalized wealth of lenders: $w = \frac{W}{Y}$
  - Beliefs: ρ

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  - Bond-issuance: $\mathcal{B}(s) \in [0, \bar{b}]$
  - Default: $\mathcal{D}(s, b') \in [0, 1]$
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- Price function: $q(s, b') \in [0, 1]$
- Market clearing: $\mathscr{L}(s, b') = b'$

Multiplicity of Equilibria

- There is a “static” multiplicity in a given period
- Arises because of timing convention: Failed auction even for small levels of bond issuances can be supported in equilibrium
- Suppose the continuation equilibrium is held constant and we consider alternative price schedules for the current period’s auction
- Normalize $Y = 1$
- Consider two scenarios for today’s auction

Scenario 1

- Today faces $q_G(s, b') > 0$ for some domain of $b' > (1 - \lambda)b$ and chooses $b^* > (1 - \lambda)b$:

$$V_1^R = u\left(1 - (r^* + \lambda)b + q_G(s, b^*)(b^* - (1 - \lambda)b)\right) + \beta\mathbb{E}\left[V(s')|s, b' = b^*\right] > V^D(s)$$

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Scenario 2

- Faces $q_B(s, b') = 0$ for all $b' > (1-\lambda)b$:

$$\begin{aligned} V_2^R &= u\left(1-(r^*+\lambda)b\right) \\ &\quad + \beta\mathbb{E}\left[V(s')|s, b'=(1-\lambda)b\right] < V^D(s) \end{aligned}$$

Evolution of Beliefs

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- If $\rho = r_V$, there is no rollover crisis this period, but $\Pr(\rho' = r_C | \rho = r_V) >> 0$
- If $\rho = r_T$, there is no rollover crisis this period and $\Pr(\rho' = r_C | \rho = r_T) < \Pr(\rho' = r_C | \rho = r_V)$
- ρ follows a three-state Markov process

Calibration

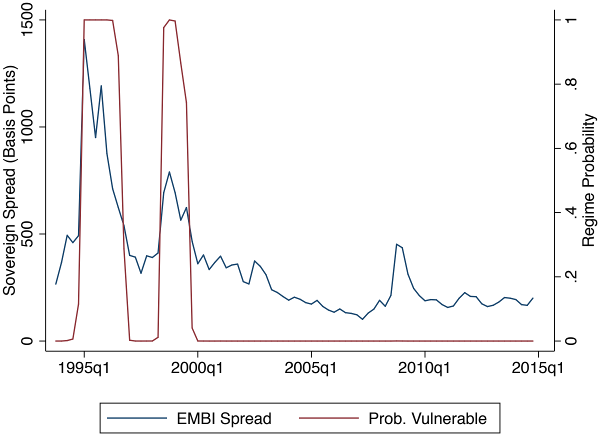
Endowment: Mexico 1980Q1-2001Q4

$(1-\rho_g)\bar{g}$	0.0034
ρ_g	0.445
σ_g	0.012
σ_z	0.003

Modest positive correlation in the growth rate g and a very small i.i.d. stochastic element z to aid in computing an equilibrium

Calibration

Beliefs



Use the forecast errors given domestic fundamentals to infer persistence of our belief process.

Calibration

Beliefs

$$\rho' = $$

$$\rho = \begin{array}{c|ccc} & \rho_T & \rho_V & \rho_C \\ \rho_T & 0.97 & 0.028 & 0.006 \\ \rho_V & 0.12 & 0.68 & 0.20 \\ \rho_C & 0.12 & 0.68 & 0.20 \end{array}$$

Tranquil regime is highly persistent, vulnerable regime modestly so.

Probability of a crisis next period given vulnerable is 20%, and given tranquil is $< 1\%$. Crises have very modest persistence and generally go back to vulnerable.

Calibration

Creditor Wealth

- Creditor wealth in model proxies for shifts in risk premium
- S&P P/E ratio is very persistent: AR(1) of 0.91
- Fit AR(1) for wealth-to-endowment:

$$w_{t+1} = (1 - \rho_w)\bar{w} + \rho_w w_t + u_{t+1},$$

- Set $\rho_w = 0.91$ based on P/E data
- Match moments in simulation for $\bar{w}$ and σ_w

Other Pre-Set Parameters

- Set λ to 0.125 (Expected maturity of 8 quarters)
- Set re-entry probability to 0.125
- Annualized risk-free rate: 0.04
- CRRA of sovereign and creditors set to 2

Matching Moments

Target Moment	Data	Model
Debt-to-Income (Quarterly)	65.6%	66.1%
Mean Spread (Annual)	3.4%	3.3%
Default Frequency (Annually)	2%	2%
R^2 Reg of Spread on Risk Measure	0.26	0.25

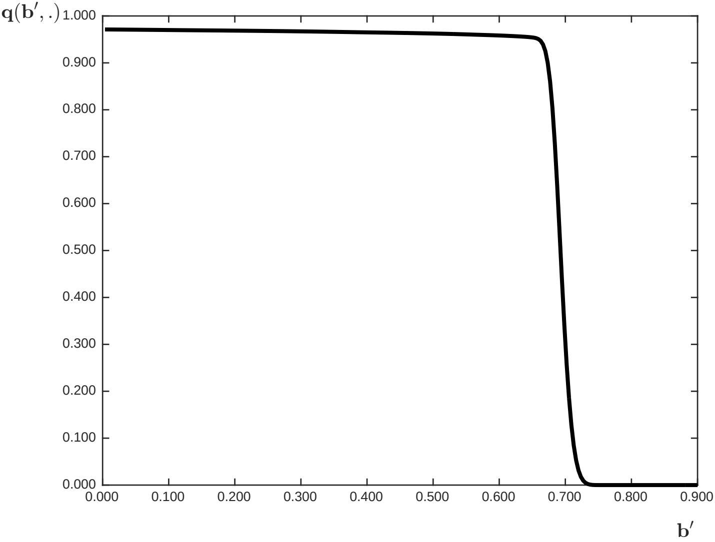
Parameter	Value
Discount factor (β)	0.835
Default Cost (d)	0.068
Mean Creditor Wealth Relative to Y ($\bar{w}$)	2.53
Std Dev Creditor Wealth (σ_w)	2.64

Model Statistics

	Mexico	Model
Default Freq.	-	2%
$E\{r - r*\}$	3.4%	3.3%
$\sigma(r - r^*)$	3%	0.2%

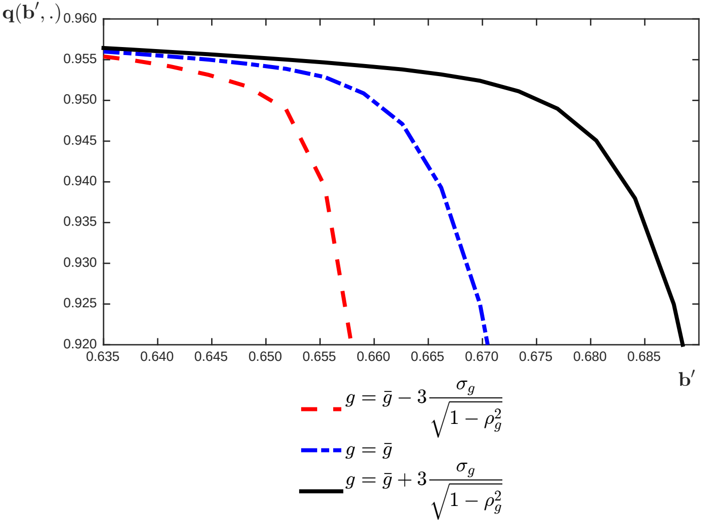
- The volatility of spreads is too low because price punishment for default risk too severe.
- Arellano (2008) does get higher volatility. But it relies on trend growth, nonlinear default costs, and highly volatile income process.
- Getting more volatility through rollover crises is focus of our new paper.

Equilibrium Price Schedule



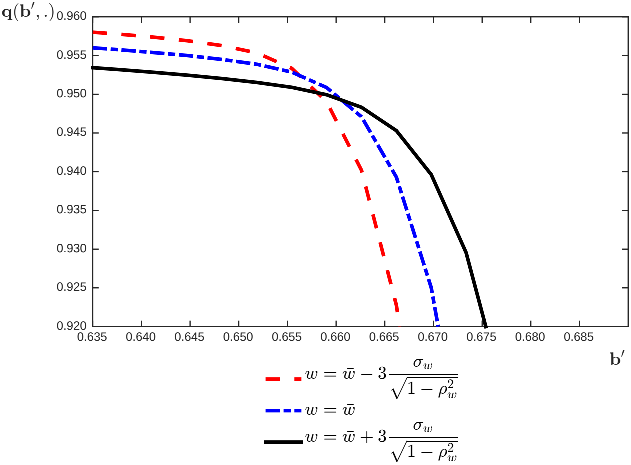
Equilibrium Price Schedule

Shocks to g



Equilibrium Price Schedule

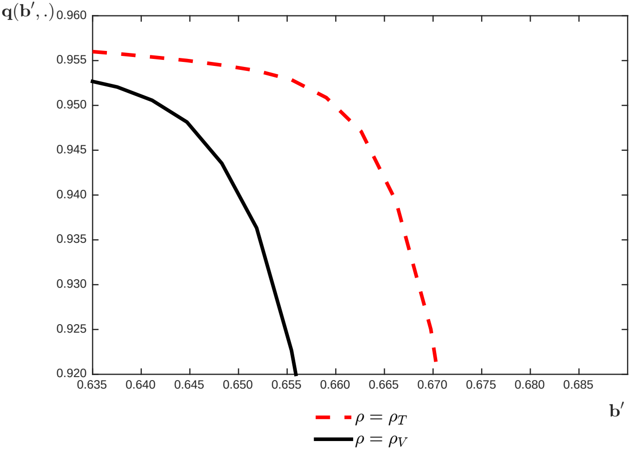
Shocks to *w*



Twisting from low future price of high b' reduces dilution.

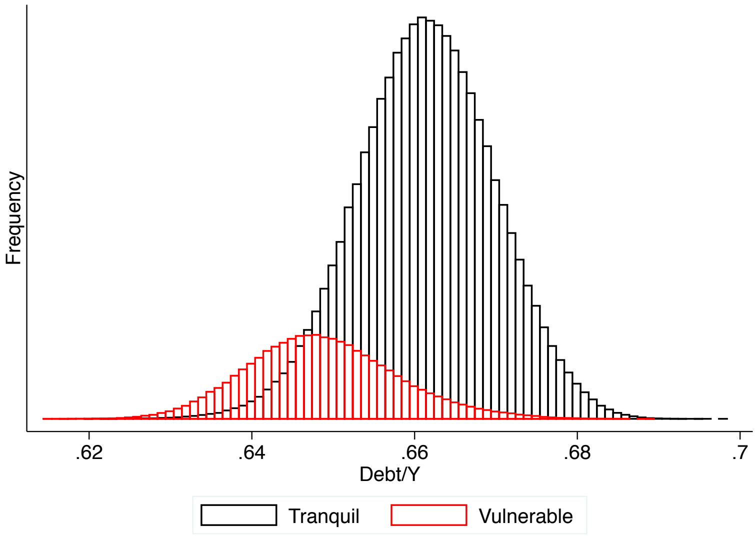
Equilibrium Price Schedule

Shocks to ρ

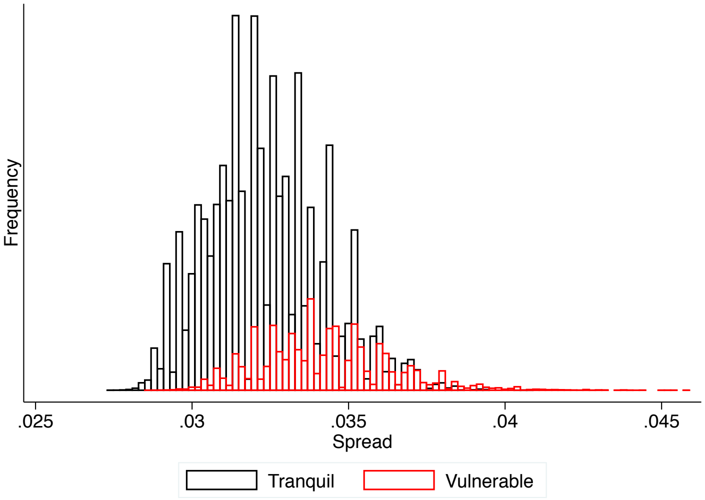


Also 0 price for actual crises.

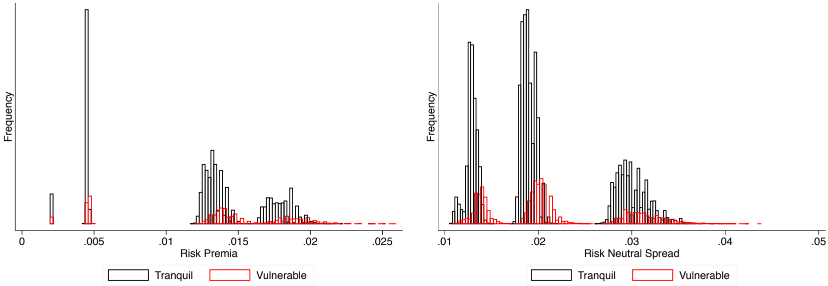
Distribution of b by Belief Regime



Distribution of $r - r^*$ by Belief Regime



Decomposition of Spread



Interest Rate Crises

	Share by Regime	Share with $\Delta y < 0$	Share with $\Delta w < 0$	Share with Belief Change to ρ_V
Tranquil	58.6	40.2	0.5	-
Vulnerable	41.4	25.1	1.0	22.6

Like our regression results:

- Domestic factors have limited predictive power.
- Fluctuations in "beliefs" important - smaller output fall to get spread rise in Vulnerable.
- Investor wealth also has limited predictive power and rises in w tend to raise spreads.
- No spread in crisis because get default - weakest aspect of model.

Default

	Share by Regime	Share with $\Delta y < 0$	Share with $\Delta w < 0$	Share with Belief Change from $(\rho_{t-1} = \rho_T)$
Tranquil	48.3	48.2	3.8	-
Vulnerable	11.4	11.4	0.8	10.3
Crisis	40.3	38.5	2.0	20.5

- Tranquil default associated with output falls.
- V & C defaults come from negative belief shifts & output falls.

Defaults

- Defaults in Tranquil regime follow a boom-bust pattern
  - Sequence of positive growth shocks generate high debt levels
  - "Surprise" low growth realization induces default
  - Potential of beliefs to shift in future still relevant
- Defaults triggered by belief regime switch are less dependent on preceding boom and subsequent bust

Default: Counterfactual Beliefs/Policies

	Share by Regime	What if Tranquil (Counterfactual)	What if Always Tranquil (Counterfactual)
Tranquil	48.3	48.3	0.1
Vulnerable	11.4	1.5	0.00
Crisis	40.3	0.0	0.0

New Paper with Desperate Deals

The treatment of rollover crises is too extreme - either nothing happens because not in the crisis zone, or default. We propose a new middle ground - a desperate deal.

Scenario 3

- Today faces $q_D(s, b') > 0$ for some domain of $b' > (1-\lambda)b$ and chooses $b^* > (1-\lambda)b$:

$$V_1^R = u\left(1 - (r^* + \lambda)b + q_D(s, b^*)(b^* - (1-\lambda)b)\right) + \beta \mathbb{E}\left[V(s')|s, b' = b^*\right] = V^D(s)$$

- Price makes indifferent, and randomizing over default today rationalizes price.
- Find that this generates high spreads and more realistic crises.

Conclusion

- Fundamentals important but business cycles incomplete description of risk
- Risk premia generate strong incentive to reduce debt
- Belief regime-switching model generates mixture of fundamental and belief-driven defaults
  - Interaction of fundamentals and potential for belief change is important
  - Sovereign can influence spreads by adjusting debt issuances (too much relative to data)
- Challenge of spread volatility is taken up in next installment with "Desperate Deals".