

# The Role of Dispersed Information in Maintaining Low Interest Rates

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# Sovereign Debt and Having Your Currency

- Countries that borrow in their own currency more resilient to debt crises
- High-debt countries: Japan vs. Italy
- High-deficit countries: UK vs. Spain Plot
- Should all countries borrow in local currency?
- Why do we have “original sin?”

## A Possible Explanation and a Puzzle

- The ability to print money avoids default risk
- $\implies$  Interest rates do not jump in anticipation of default
- ... but printing money will cause inflation...
- $\implies$  Interest rates should jump in anticipation of inflation
- Our story: **Information frictions** underlie differential response of bond prices to shocks

## The “Original Sin”

- Some countries seem to be unable to issue domestic debt
- Perhaps because of time-inconsistency (Calvo, 1989, Engel and Park, 2016)
- If this were the problem, we would expect interest rates to be *more* sensitive to bad news with domestic-currency debt
- Bordo-Meissner (2006): Currency mismatch not necessarily associated with more frequent crises
- Ability to devalue and mitigate recession not always relevant (in the 2008 crisis the yen appreciated)

## Related Papers on Information

- Grossman-Stiglitz (1980)
- Bayesian trading game: Hellwig, Mukherji, Tsyvinski (2006), Albagli, Hellwig, and Tsyvinski (2011), Allen, Morris, and Shin (2006)

# Plan of the Talk

- Model: a two-period Bayesian trading game
- Analyze comparative statics with respect to relevant information precision
- Parameterization
- Numerical results

- Auctions one unit of debt in period 1 (per capita per young strategic trader), price  $q_1$ 
  - ▶ Foreign currency debt: Debt promise to pay 1 unit of goods in period 3 (foreign price level = 1)
  - ▶ Domestic currency debt: debt promise a nominal amount 1 in period 3
- In period 3, gov't collects taxes, depending on the realization of  $\theta \sim N(\mu_0, 1/\alpha_0)$ :
  - ▶ If  $\theta \geq \bar{\theta}$ , full repayment
  - ▶ Otherwise, gov't pays back  $\delta < 1$ :
    - ★ Under foreign currency, default, haircut  $1 - \delta$
    - ★ Under domestic currency, full nominal repayment, but FTPL implies a jump in the price level

## Private agents: Preferences and Technology

- 2 OLGs living for two periods
- Endowed with goods when young
- Want to consume when old, risk neutral
- Strategic traders:
  - ▶ Can store
  - ▶ Can buy one unit of government bonds
- Noise traders:
  - ▶ Demand an (unobserved) fraction  $\Phi(\epsilon_t^b)$ ,  $\epsilon_t^b \sim N(0, 1/\psi_t^b)$ , of gov't debt

## Agent “Labels”

- Period 1: bondholders (sophisticated, have more precise information)
- Period 2:
  - ▶ Foreign currency: new gen. of sophisticated bondholders
  - ▶ Domestic currency: gov't can print money, so pivotal agents are price setters (less precise information)

## Two Cases

- ① Warm-up: No recall of past prices
- ② Partial recall of past prices

## The Simplest Case

- period-2 agents do not observe  $q_1$

Period- $t$  agents' information set

- prior
- private signal of  $\theta$ :  $x_{i,t}$ , with conditional precision  $\beta_t$
- can condition on period- $t$  price  $\Rightarrow$  demand schedules  $d(x_{i,t}, q_t)$

# Equilibrium Definition

## Definition

A Perfect Bayesian Equilibrium consists of bidding strategies  $d(x_{i,t}, q_t)$  for strategic players, a price function  $q(\theta, \epsilon_t)$  and posterior beliefs  $p(x_{i,t}, q_t)$  such that

- (i)  $d(x_{i,t}, q_t)$  is optimal given beliefs  $p(x_{i,t}, q_t)$ ,
- (ii)  $q(\theta, \epsilon_t)$  clears the market for all  $(\theta, \epsilon_t)$ , and
- (iii)  $p(x_{i,t}, q_t)$  satisfies Bayes' Law for all market clearing prices  $q_t$ .

## Period-2 Agents: Payoffs and Strategies

- Expected payoff

$$\underbrace{\delta \cdot \text{Prob}(\theta < \bar{\theta} | x_{i,2}, q_2) + 1 \cdot \text{Prob}(\theta \geq \bar{\theta} | x_{i,2}, q_2)}_{\begin{array}{ll} (\text{foreign currency}) & \mathbb{E}_{i,2}[\text{bond repayment}] \\ (\text{domestic currency}) & \mathbb{E}_{i,2}[\text{inverse inflation}] \end{array}} - q_2$$

- Posterior beliefs on  $\theta$  are FOSD-increasing in  $x_{i,2}$ 
  - ▶ Buy if signal is above threshold:

$$d(x_{i,2}, q_2) = \mathbb{1}[x_{i,2} \geq \hat{x}_2(q_2)]$$

## Period-2: Market Clearing and Beliefs

- Period-2 market clearing condition

$$\underbrace{\text{Prob}(x_{i,2} \geq \hat{x}_2(q_2) | \theta)}_{\text{informed nominal-asset demand}} = \underbrace{1 - \Phi(\epsilon_2)}_{\text{nominal-asset supply (net of noise agents)}}$$

- Market clearing implies

$$z_2 := \theta + \frac{\epsilon_2}{\sqrt{\beta_2}} = \hat{x}_2(q_2)$$

- We focus on equilibria where  $z_t$  is informationally equivalent to  $q_t$
- Second-period agents posterior beliefs

$$\theta | x_2, z_2 \sim N \left( \frac{\alpha_0 \mu_0 + \beta_2 x_2 + \beta_2 \psi_2 z_2}{\alpha_0 + \beta_2 (1 + \psi_2)}, \frac{1}{\alpha_0 + \beta_2 (1 + \psi_2)} \right)$$

## Period-2: Equilibrium

- Marginal agent's indifference condition

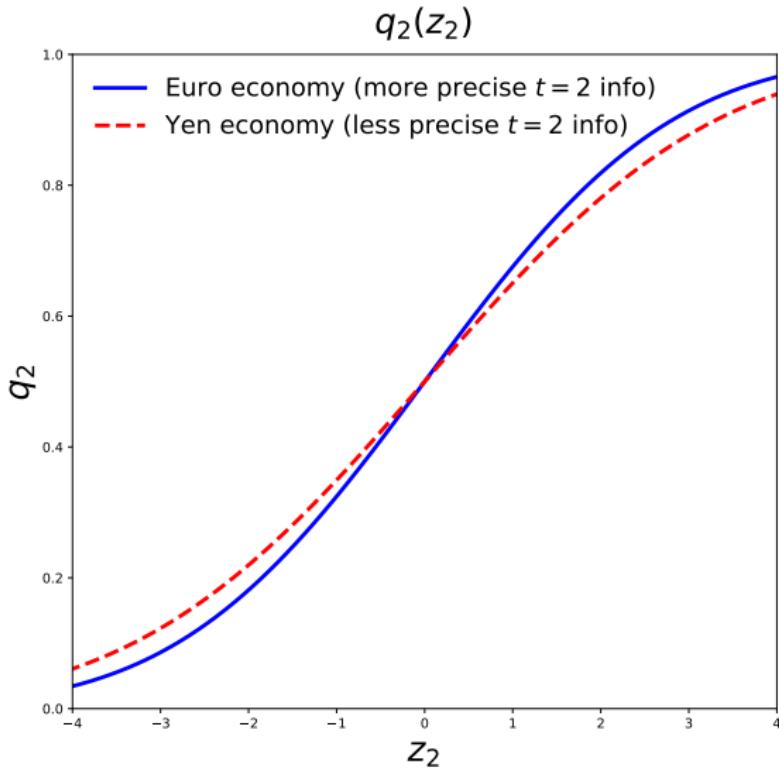
$$\delta + (1 - \delta) \text{Prob}(\theta \geq \bar{\theta} | x_{i,2} = \hat{x}_2(q_2), q_2) = q_2$$

- Equilibrium  $t = 2$  price

$$q_2(z_2) = \delta + (1 - \delta) \Phi \left( \frac{(1 - w_S)\mu_0 + w_S z_2 - \bar{\theta}}{\sigma_S} \right)$$

$$w_S := \frac{\beta_2(1+\psi_2)}{\alpha_0 + \beta_2(1+\psi_2)}, \quad \sigma_S^2 := \frac{1}{\alpha_0 + \beta_2(1+\psi_2)}$$

# Comparative Statics (more precise info = higher $\beta_2$ or $\psi_2$ )



## Period-1: Strategies and Beliefs

- Expected payoff

$$\mathbb{E}[q_2(z_2)|x_{i,1}, q_1] - q_1$$

- ▶  $q_2$  is increasing in  $z_2$
- ▶ posterior beliefs are FOSD-increasing in  $x_{i,1}$
- Monotone threshold strategies again Demand schedules still monotone:  $d(x_{i,1}, q_1) = \mathbb{1}[x_{i,1} \geq \hat{x}_1(q_1)]$
- Market clearing implies

$$z_1 := \theta + \epsilon_1 / \sqrt{\beta_1} = \hat{x}_1(q_1)$$

- ▶ again,  $z_1$  observationally equivalent to  $q_1$
- First-period agents posterior beliefs on  $z_2$ , not just  $s$

$$z_2|(z_1, x_1) \sim N\left(\frac{\alpha_0 \mu_0 + \beta_1 x_1 + \beta_2 \psi_1 z_1}{\gamma_1}, \frac{1}{\gamma_1} + \frac{1}{\psi_2 \beta_2}\right)$$

$\gamma_1$

## Period-1: Equilibrium

- Marginal traders' indifference condition

$$\mathbb{E}[q_2(z_2)|x_{i,1} = \hat{x}_1(q_1), q_1] = q_1$$

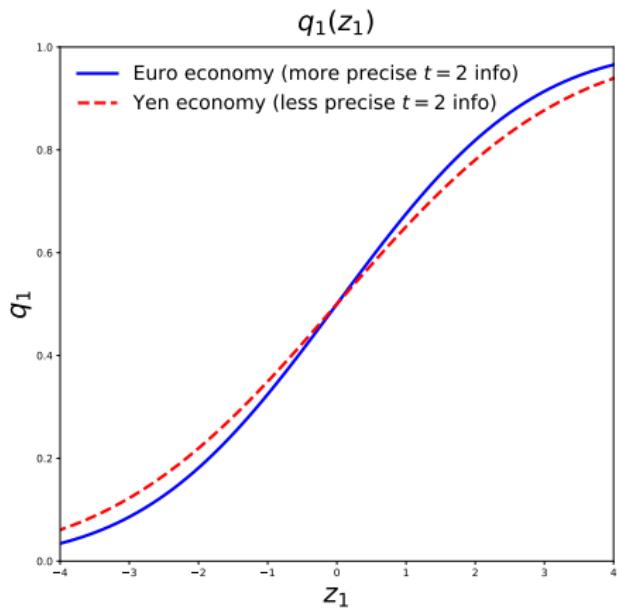
- Equilibrium  $t = 1$  price

$$q_1(z_1) = \delta + (1 - \delta)\Phi \left[ \frac{\mu_0 - \bar{\theta}}{\sqrt{w_S^2 \sigma_{S|B}^2 + \sigma_S^2}} + \frac{w_S w_B}{\sqrt{w_S^2 \sigma_{S|B}^2 + \sigma_S^2}}(z_1 - \mu_0) \right]$$

$$w_B := \frac{\beta_1(1+\psi_1)}{\alpha_0 + \beta_1(1+\psi_1)}, \quad \sigma_{S|B}^2 := \frac{1}{\gamma_1} + \frac{1}{\psi_2 \beta_2}$$

$q_1$  with recall

# Comparative Statics (more precise info = higher $\beta_2$ or $\psi_2$ )



Propositions 1&2

## (Partial) Recall of the First-Period Price

- Now, add a signal of first-period price, observed by second-period agents
- In the equilibrium we constructed,  $z_1$  was informationally equivalent to  $q_1$
- Make the signal about  $z_1$ : period-2 agents observe  $\rho := z_1 + \sigma_\eta \eta_1$ ,  $\eta_1 \sim N(0, 1)$
- Implies that signal is more precise in the (flat) tails

## New equilibrium

Period-2 price:

$$q_2(z_2, \rho) = \delta + (1 - \delta)\Phi\left(\frac{(1 - w_\rho - w_2)\mu_0 + w_2 z_2 + w_\rho \rho - \bar{\theta}}{\sigma_2}\right)$$

$$w_\rho := \frac{\tau_\rho}{\alpha_0 + \beta_2 + \tau_{q_2} + \tau_\rho}$$

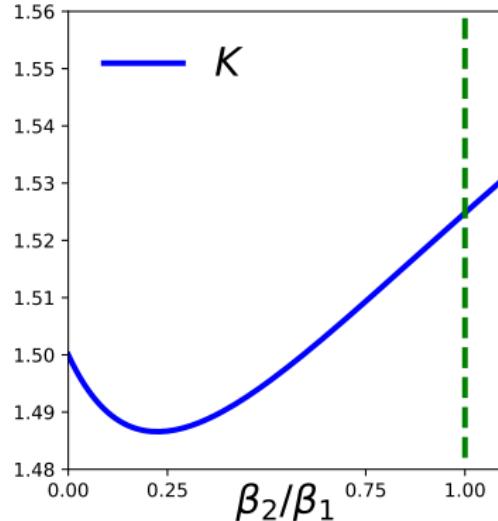
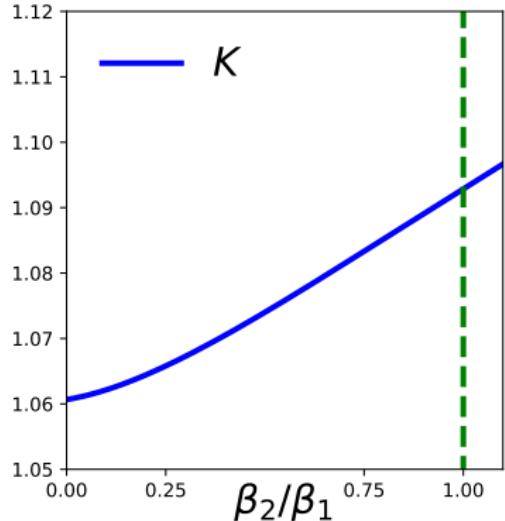
$$w_2 := \frac{\beta_2 + \tau_{q_2}}{\alpha_0 + \beta_2 + \tau_{q_2} + \tau_\rho}$$

- $\tau_\rho$  : precision of signal  $\rho$  about  $\theta$
- $\tau_{q_2}$ : precision of  $z_2$  about  $\theta$

*p<sub>1</sub> price*

# Comparative Statics

$t = 1$  Price Responsiveness



Propositions 3&4

## Numerical Challenges

- Model is a bit too simplistic for a full calibration
- Binary payoff
- 3-periods, with debt issued only once
- Two restrictions are too tight for the data:
  - ▶ Binary payoff implies tight connection between mean spreads and standard deviations
  - ▶ Pure Bayesian learning implies bounded degree of disagreement, UK households did not get the memo
- We choose parameter values that deliver a good fit, but are also reasonable
- (Calibration tends to push  $\psi$  and/or  $\beta$  to 0)

## Data

- We will use UK data
- Has liquid market for inflation-protected securities
- $\Rightarrow$  can disentangle real risk-free rate from inflation expectations
- Also, we have good micro data on inflation expectations
  - ▶ Unsophisticated agents (period-2 agents): Bank of England / Ipsos Inflation Attitudes Survey (UK population)
  - ▶ Sophisticated agents (period 1): Professional forecasters as reported in UK Treasury “Forecasts for the UK Economy: a comparison of independent forecasts.”
- Externally set parameter:  $\delta = 0.63$  (calibrated to recovery rate from sovereign debt in Cruces and Trebesch, 2013)

## Moments that we use - part 1

Data	Model
Avg inflation spreads on gilts	Avg. period-1 yield to maturity $(1/q_1 - 1)$
St dev of inflation spreads	St. dev of period-1 YTM
St dev of inflation	St. dev of $1/q_2$ (price at which sellers accept money in period 2)

## Moments that we use - part 2

Data	Model
Avg cross-sectional dispersion of inf forecast: professional	$D_1 := \sqrt{\frac{\mathbb{V}(\mathbb{E}[\theta   x_{i,1}, z_1]   \theta, z_1)}{\mathbb{V}(\theta)}} = \frac{\sqrt{\alpha_0 \beta_1}}{\alpha_0 + \beta_1 + \tau_{q_1}}$
Avg cross-sectional dispersion of inf forecast: UK population	$D_2 := \sqrt{\frac{\mathbb{V}(\mathbb{E}[\theta   x_{i,2}, z_2, \rho]   \theta, z_2, \rho)}{\mathbb{V}(\theta)}} = \frac{\sqrt{\alpha_0 \beta_2}}{\alpha_0 + \beta_2 + \tau_{q_2} + \tau_\rho}$
Avg reporting error about <i>current</i> inflation by UK population	$\text{FEV}_\rho := \frac{\mathbb{V}(z_1   \rho)}{\mathbb{V}(z_1)} = \frac{\tau_{z_1}}{\tau_\eta + \tau_{z_1}}$

Note: all data moments normalized by st. dev. of inflation

## Parameter Configuration

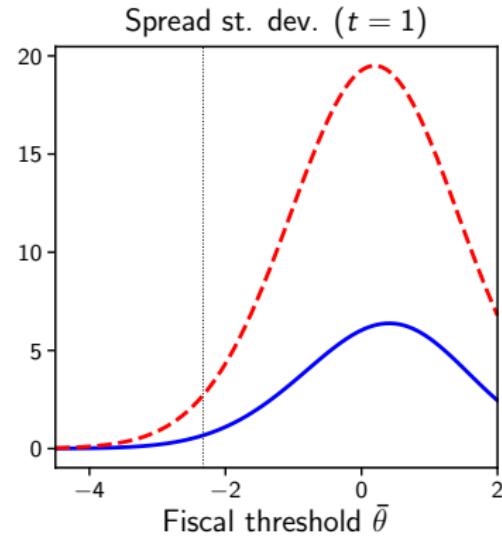
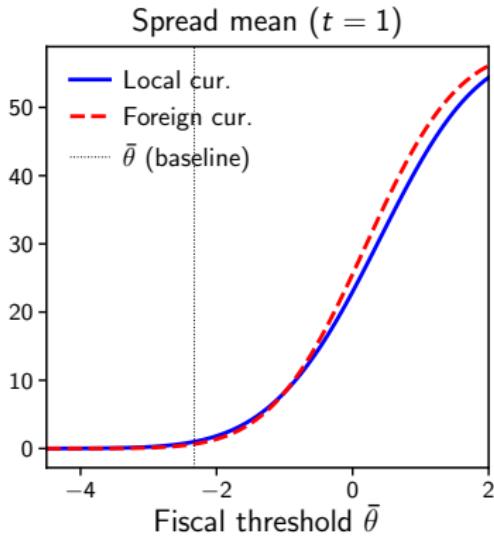
Variable	Value	Target	Model	Data
$\bar{\theta}$	-2.33	Breakeven inflation spreads (mean)	1.00	1.07
$\psi_1$	1.80	Breakeven inflation spreads (st. dev.)	0.68	0.49
$\psi_2$	0.35	YoY CPI Inflation (st. dev.)	2.97	3.44
$\beta_1$	1.04	Informed forecast dispersion (mean)	0.26	0.20
$\beta_2$	0.24	Uninformed forecast dispersion (mean)	0.33	0.49
$\tau_\eta$	0.15	Uninformed error on past inflation (mean)	0.59	0.24

# Counterfactuals

- More precision
  - ▶  $\beta_2 = \beta_1, \psi_2 = \psi_1, \tau_\eta = \infty$
  - ▶ Interpretation: foreign-currency debt, second-period agents are sophisticated bondholders
- Perfect information benchmark:  $\theta$  common knowledge ex ante

Statistic	Baseline	Counterfactuals	
		More precision	Perfect info
Bond spreads (mean)	1.00	0.65	0.58
Bond spreads (st. dev.)	0.68	2.72	5.83
Inflation (st. dev.)	2.97	3.47	5.83

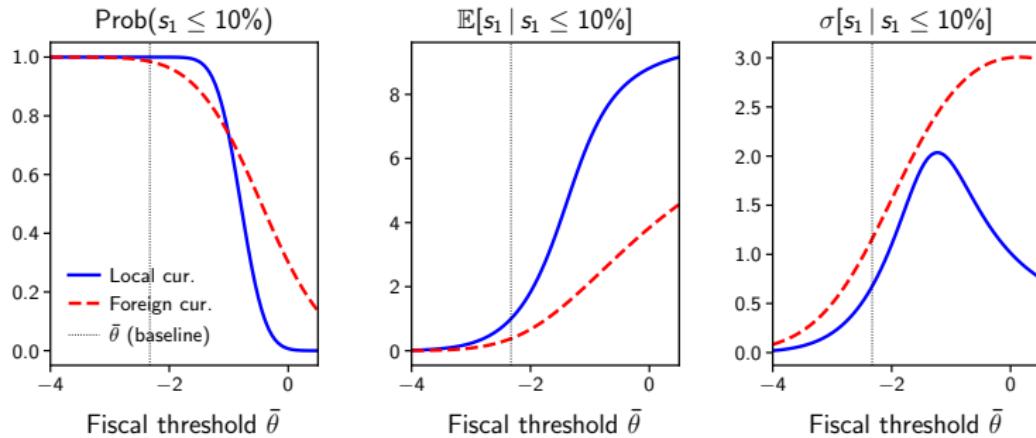
# The role of default risk



## Is local currency always good?

- Previous picture: must always issue debt (even at 60% spread)
- What if gov't gives up issuing debt above some threshold?
- Let the threshold be 10%

# Debt issuance under a threshold rule



## Contrast to “Argentina”: Moments that we Adapt

Data	Model
Avg spread on 5-year CDS	Avg. period-1 yield to maturity $(1/q_1 - 1)$
St dev of CDS spreads	St. dev of period-1 YTM
Avg cross-sectional dispersion of inf forecast: professional	$D_1 := \sqrt{\frac{\mathbb{V}(\mathbb{E}[\theta   x_{i,1}, z_1]   \theta, z_1)}{\mathbb{V}(\theta)}} = \frac{\sqrt{\alpha_0 \beta_1}}{\alpha_0 + \beta_1 + \tau q_1}$

## Argentina Parameters: Other Details

- Use dispersion of inflation forecast as a proxy, assume same ratio of dispersion to volatility for inflation and default risk
- (Drop periods with 100% annual inflation to compute moment above)
- Set  $\delta = 0.25$  (standard for distressed economies, with  $\delta = 0.63$  spread too small even with 100% default prob).
- Baseline: foreign currency, so  $\beta_2 = \beta_1$ ,  $\psi_2 = \psi_1$ ,  $\tau_\eta = \infty$
- Counterfactual (domestic currency): choose same ratio  $\beta_2/\beta_1$  and  $\psi_2/\psi_1$  and same  $\tau_\eta$  as UK

## Argentina Parameter Values

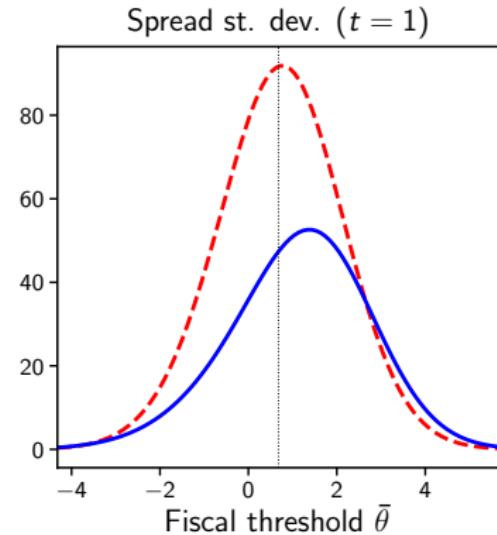
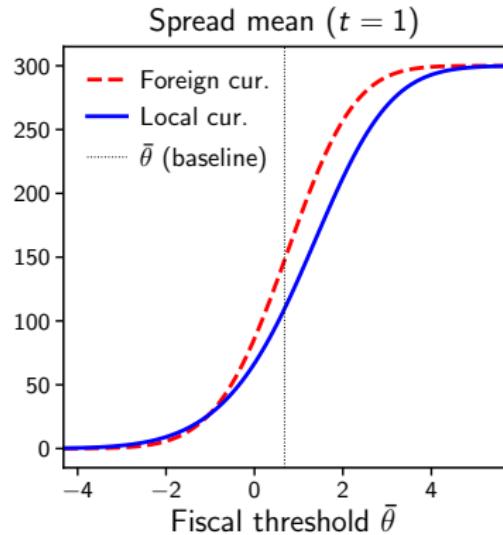
Table: Parameter configuration.

Variable	Value	Target	Data	Model
$\bar{\theta}$	0.68	CDS upfront price (mean)	47.25	47.25
$\psi_1$	1.91	CDS upfront price (st. dev.)	19.79	19.79
$\beta_1$	0.44	Informed forecast dispersion (mean)	0.37	0.37

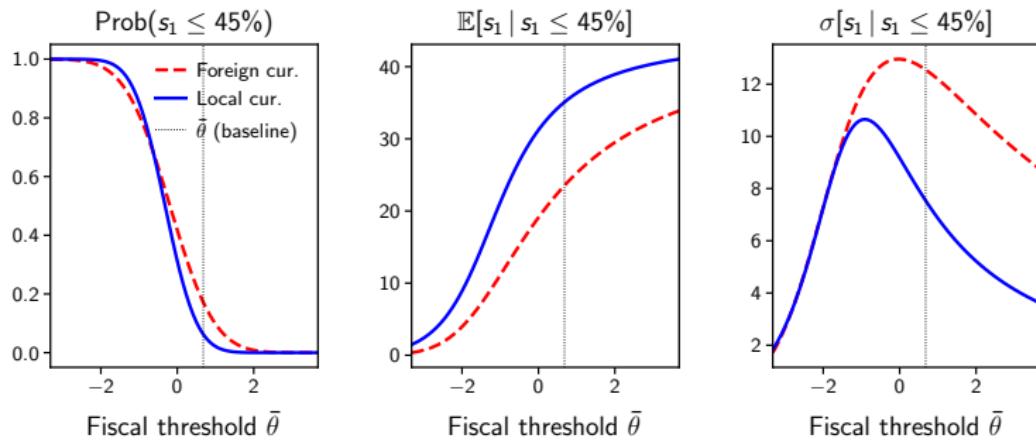
## Argentina Counterfactuals

Statistic	Baseline	Counterfactuals	
		Less precision	Perfect info
CDS upfront price (mean)	47.3	50.1	43.6
CDS upfront price (st. dev.)	19.8	11.2	32.4

# Comparative Statics wrt $\bar{\theta}$



# Threshold rule at 45%



# Conclusion

- Heterogeneity of information has important implications for debt management
- Domestic-currency debt more resilient to bad news
- As prior becomes worse, even more valuable to issue domestic-currency debt
- Eventually, it is so expensive that might as well concentrate debt issuance in the good states
- A theory of original sin: bad prior  $\implies$  only sophisticated agents willing to buy (sometimes)

# THANK YOU!

## Setup and actors

- Three periods
- Bond traders: strategic and noise
- Workers: strategic and noise
- Government (described by a mechanical rule)

# Workers: Preferences and Technology

- Only alive in periods 2 and 3
- Strategic workers
  - ▶ One unit of endowment in period 2
  - ▶ Wish to consume in period 3, risk neutral
  - ▶ Can store good (zero return) or sell it
- Noise workers
  - ▶ (Unobserved) relative mass  $\Phi(\epsilon_2^w)$ ,  $\epsilon_2^w \sim N(0, 1/\psi_2^w)$
  - ▶ Can produce in period 3
  - ▶ Demand 1 unit of consumption in period 2

# Bond Traders: Preferences and Technology

- 2 OLGs living for two periods
- Endowed with goods when young
- Want to consume when old, risk neutral
- Strategic traders:
  - ▶ Can store
  - ▶ Can buy one unit of government bonds
- Noise traders:
  - ▶ Demand an (unobserved) fraction  $\Phi(\epsilon_t^b)$ ,  $\epsilon_t^b \sim N(0, 1/\psi_t^b)$ , of gov't debt
- Mass of bond traders negligible compared to workers

## Government - “Euro” scenario

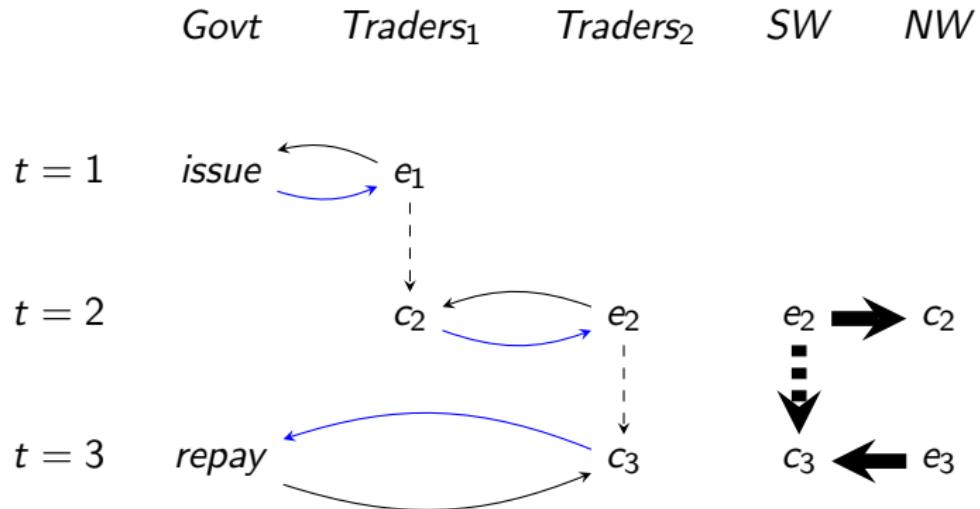
- Auctions one unit of debt in period 1 (per capita per young strategic trader), price  $q_1$
- Debt is a promise to pay  $\hat{s}(q_1)$  Euros (goods) in period 3. Examples:
  - ▶  $\hat{s}(q_1) \equiv 1$  (Eaton and Gersovitz)
  - ▶  $\hat{s}(q_1) \equiv 1/q_1$  (Calvo)
- In period 3, gov't collects taxes, depending on the realization of  $s \sim N(\mu_0, 1/\alpha_0)$ :
  - ▶ If  $s \geq \hat{s}(q_1)$ , full repayment
  - ▶ Otherwise, haircut  $1 - \delta$ , gov't pays back  $\delta\hat{s}(q_1)$

## Government - “Yen” scenario

- Auctions one unit of debt in period 1 (per capita per young strategic trader), price  $q_1$
- Debt is a promise to pay  $\hat{s}(q_1)$  Yens.
- In period 2, gov't prints Yen, pays debt back.
- In period 3, gov't collects taxes, depending on the realization of  $s \sim N(\mu_0, 1/\alpha_0)$ :
  - If  $s \geq \hat{s}(q_1)$ , collects  $\hat{s}(q_1)$
  - Otherwise, collects  $\delta\hat{s}(q_1)$

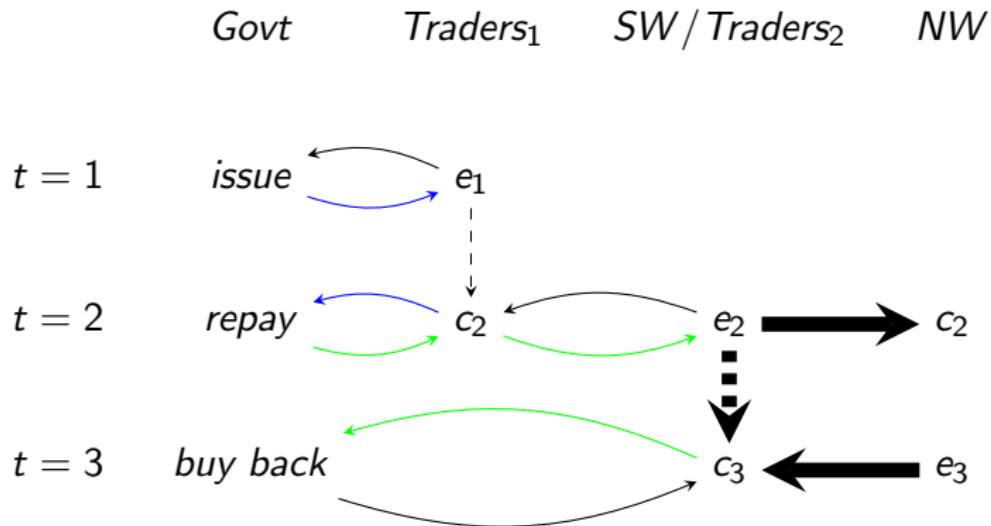
} (same as Euro scenario)
- Period-3 taxes used to buy Yen back. Price level is either 1 or  $1/\delta$ .

# Euro Markets



goods; **bonds**; storage (dashed)

# Yen Markets



## Euro vs. Yen: the Key Difference

- Eventual default/inflation is the same at the end, period 3
- Identity of primary-market participants the same at the beginning, period 1
- **Period 2** Identity of secondary-market participants different:
  - ▶ Under Euro, bonds offloaded to new bond traders
  - ▶ Under Yen, offloaded to workers (through cash)

## Period 2: Euro vs. Yen

	Euro	Yen
Identity of marginal buyer	bond trader	worker
Goods given up Goods received: w/o default/inflation: with default/inflation:	$\hat{s}(q_1)q_2$ $\hat{s}(q_1)$ $\delta\hat{s}(q_1)$	1 $P_2/P_3 = P_2$ $P_2/P_3 = \delta P_2$

Collapse the 2 scenarios into a single problem: in the Yen case  $q_2 := 1/P_2$

# Information

- Strategic traders observe  $s + \xi_{i,t}^b$ , with  $\xi_{i,t}^b \sim N(0, 1/\beta_t^b)$
- Strategic workers observe  $s + \xi_{i,2}^w$ , with  $\xi_{i,2}^w \sim N(0, 1/\beta_2^w)$
- Comparative statics with respect to:
  - ▶  $\beta_2^w$  vs.  $\beta_2^b$  signal precision
  - ▶  $\psi_2^w$  vs.  $\psi_2^b$  (inverse of) confusion from noise traders

# Precision of first-period posterior beliefs

- Precision of first-period posterior beliefs

$$\frac{1}{\gamma_1} := \frac{1}{\alpha_0 + \beta_1(1 + \psi_1)}$$

Case 1: beliefs

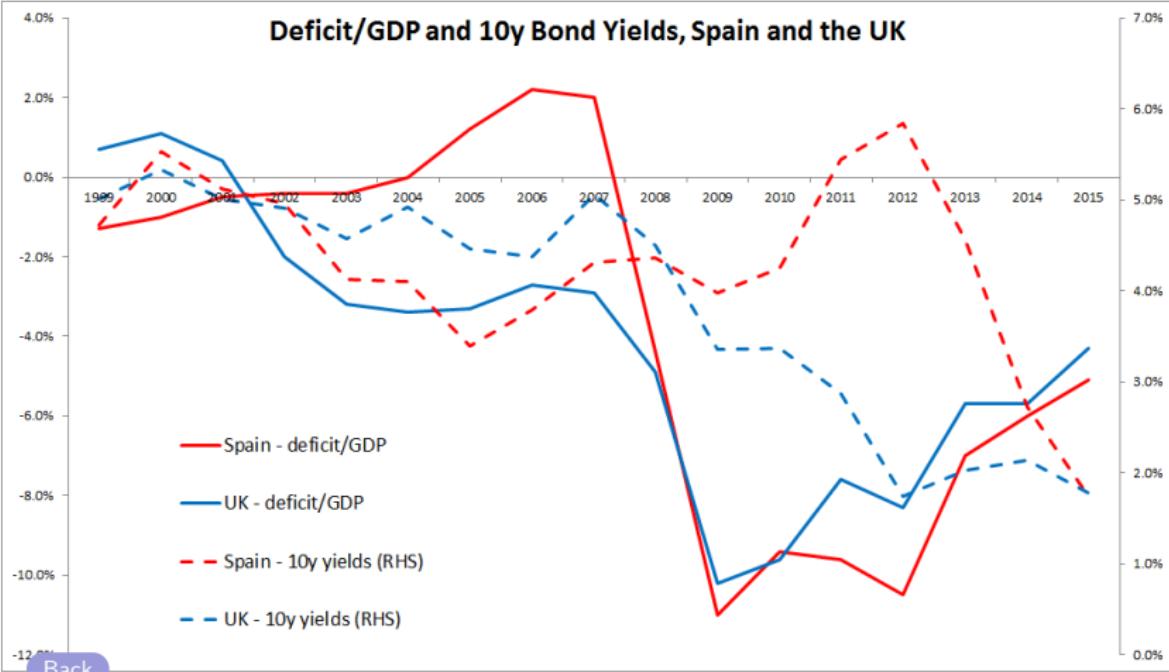
Case 1: comp stat

- Aggregate noise term of first-period price (case with recall)

$$S := \sqrt{w_{2,S}^2 \left( \frac{1}{\gamma_1} + \frac{1}{\beta_2 \psi_2} \right) + \sigma_S^2}$$

Back

## Deficit/GDP and 10y Bond Yields, Spain and the UK



Back

## Period-1 price with partial recall

$$q_1(z_1) = \delta + (1 - \delta)\Phi\left(\frac{\mu_0(1 - w_\rho - w_2 w_1) + z_1(w_\rho + w_2 w_1) - \bar{\theta}}{\sqrt{w_2^2 \sigma_{2|1}^2 + w_\rho^2 \sigma_\eta^2 + \sigma_2^2}}\right)$$

$$\sigma_{2|1}^2 := \frac{1}{\alpha_0 + \beta_1 + \tau_{q_1}} + \frac{1}{\tau_{q_2}}$$

$$w_1 := \frac{\beta_1 + \tau_{q_1}}{\alpha_0 + \beta_1 + \tau_{q_1}}$$

$\tau_{q_1}$ : precision of information embedded in first-period price [Back to period-2 price](#)

## Comparative Statics: Some Intuition

$$q_1(z_1) = \delta + (1 - \delta)\Phi\left[\frac{\mu_0 - \bar{\theta}}{S} + K(z_1 - \mu_0)\right]$$

$$K := \frac{(w_{1,S} + w_{2,S}w_B)}{\sqrt{w_{2,S}^2 \left(\frac{1}{\gamma_1} + \frac{1}{\beta_2 \psi_2}\right) + \sigma_S^2}}$$

- Always get single crossing, as before
- Direction of crossing dictated by  $K$
- Effect of  $\beta_2, \psi_2$  on  $K$  more involved:
  - ▶  $\beta_2 \uparrow \implies$  period-2 agents give less weight to prior, but also to  $q_1$
  - ▶ Less weight on prior  $\implies q_2$  tracks  $s$  better
  - ▶ Less weight on  $q_1 \implies q_2$  tracks  $s$  better, but potentially less correlated with  $q_1$ , ambiguous

[Back to period-2 price](#)