Self-Fulfilling Debt Crises: A Quantitative Analysis

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European Debt Crisis

- Prior to 2008, little difference in yields on Government bonds issued by countries in the euro area
    - Yields differentials (spreads) between Italian and German bonds averaged 10 basis points over the 2000-2008 period
- After 2008, spreads between bonds issued by peripheral countries and Germany opened up substantially
    - In 2011, the ITA-GER bond spread achieved 500 basis points
- Two views to interpret movements in spreads
    - “Fundamental view": emphasizes role of weak economic conditions
        - Broad interpretation of weak economic conditions
    - “Sunspot view": emphasizes role of coordination failures
- These views have different policy implications

Distinguishing the Two Views

- When applied to the Euro crisis, difficult to distinguish these views based on the behavior of economic fundamentals and spreads
- Peripheral countries in Europe: deep recessions and poor fundamentals
  - Might increase spreads by themselves
  - Might raise the potential for coordination failures, and therefore spreads
- So need other information to distinguish these views
- We build a model that nests these two views, and use their implications for other variables to distinguish them
  - **Key insight**: The two views have different implications for the behavior of the maturity structure of government debt
  - **Our approach**: Use the restrictions implied by the theory, along with observed maturity choices, to evaluate these two views

What We Do

- Nest views in sovereign debt model: Three ingredients
  - Endogenous maturity structure of Government debt
  - Shocks to economic fundamentals
  - Sunspot shocks triggering self-fulfilling rollover crises
    - Gov't may default because of coordination failures among lenders
- Spreads vary over time because of changes in economic fundamentals and changes in the expectation of future rollover crises
  - Debt maturity helps distinguish between these two sources of risk
- (Overly) Simple intuition
  - *Spreads high because of rollover risk* $\Rightarrow$ Gov't lengthens maturity
  - *Spreads high because of fundamentals* $\Rightarrow$ Gov't shortens maturity

Quantitative Analysis

- Fit model to Italian data
- Quantify the sources of the 2008-2012 crisis
  - Rollover risk accounts for only $\approx 10\%$ of Italian spreads
  - Fundamental risk accounts for $\approx 60\%$ of Italian spreads
- Show that debt maturity data play critical role in measurement
- Use model to conduct policy exercise
  - Evaluate whether the ECB bond purchasing program of 2012 (OMT) can be classified as lending of last resort

Related Literature

1 Multiple equilibria in models of sovereign debt:

- Rollover crises: Alesina et al. (1987), Cole and Kehoe (2000), Conesa and Kehoe (2015), Aguiar et al (2015), Aguiar et al. (2016)
- Other types of multiplicity: Calvo (1988), Lorenzoni and Werning (2015), Aires et al. (2015), Aguiar and Amador (2015)

2 Permanent vs. transitory income shocks and PIH: Cochrane (1994), Aguiar and Gopinath (2007)

3 Quantitative models of sovereign defaults: Arellano and Ramanarayanan (2012), Sanchez et al. (2015), Bai et al. (2015), Borri and Verdhelan (2014)

4 Quantitative analysis of models with multiple equilibria: Jovanovic (1989), Tamer (2003), Aruoba, Cuba-Borda and Schorfheide (2016)

Overview of the Talk

1. The Model
2. Maturity choices and sources of default risk
   - Highlight basic trade-offs in model
   - An historical example: Italy in the 1980s
3. Quantitative Analysis
4. Decomposing Italian spreads
5. ECB Bond Purchasing Program

The Model

Environment

- $t = 0, 1, 2, ...$ is discrete. Exogenous states: $s_t = (s_{1,t}, s_{2,t})$
  - $s_{1,t}$ are shocks that affect preferences/endowments
  - $s_{2,t}$ are pure coordination devices (sunspots)

- Government:
  - Receives tax revenues every period: $Y_t = Y(s_{1,t})$
  - Preferences over government expenditures $\{G_t\}_{t=0}^{\infty}$

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(G_t)$$

- Lenders:
  - Evaluate streams of payments $\{d_t\}_{t=0}^{\infty}$ using $M_{t,t+1} = M(s_{1,t}, s_{1,t+1})$

$$\mathbb{E}_0 \sum_{t=0}^{\infty} M_{0,t} d_t$$

Market Structure

- Gov't enters time t with payments due to the lenders. Payments are indexed by (B_t, λ_t)
  - B_t controls total amount issued, λ_t controls decay rate of payments

Time of Payments	Promised Payments
t	B_t
$t+1$	$(1-\lambda_t)B_t$
$t+2$	$(1-\lambda_t)^2 B_t$
$\dots$	$\dots$
$t+j$	$(1-\lambda_t)^j B_t$

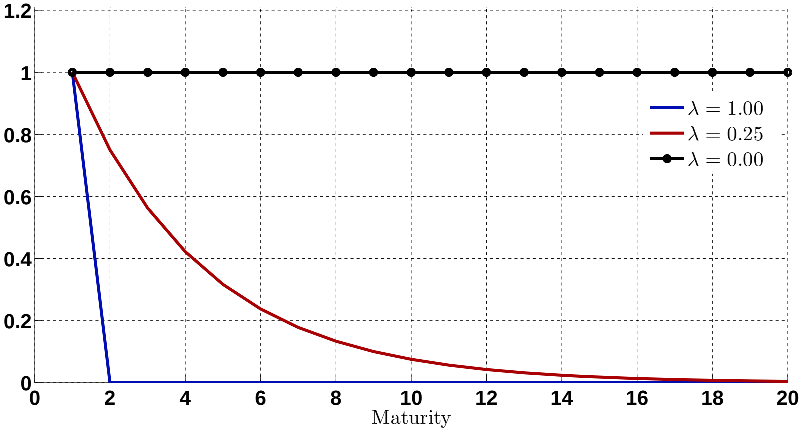
Face value of debt: $\frac{B_t}{\lambda_t}$, **Average life** of debt: $\frac{1}{\lambda_t}$

Interpretation: Gov't issued a restricted portfolio of zero coupon bonds

- Allow for changes in maturity with manageable state space

Market Structure

- Gov't enters time t with payments due to the lenders. Payments are indexed by (B_t, λ_t)
  - Different combinations of (B_t, λ_t) imply different maturity structure of debt



Market Structure

- Gov't enters time t with payments due to the lenders. Payments are indexed by (B_t, λ_t)
  - Government selects (B_{t+1}, λ_{t+1}) taking as given price schedules for zero coupon bonds maturing in j periods $\{q_{j,t}\}_j$

Time	New Promises	Old Promises	New Issuances/Buy-backs
t		B_t	
$t+1$	B_{t+1}	$(1-\lambda_t)B_t$	$[B_{t+1}-(1-\lambda_t)B_t]$
$t+2$	$(1-\lambda_{t+1})B_{t+1}$	$(1-\lambda_t)^2B_t$	$[(1-\lambda_{t+1})B_{t+1}-(1-\lambda_t)^2B_t]$
...	...	...	...
$t+j$	$(1-\lambda_{t+1})^{j-1}B_{t+1}$	$(1-\lambda_t)^jB_t$	$[(1-\lambda_{t+1})^{j-1}B_{t+1}-(1-\lambda_t)^jB_t]$

Net revenues from debt market:

$$\Delta_t = \sum_{j=1}^{\infty} q_{j,t}[(1-\lambda_{t+1})^{j-1}B_{t+1} - (1-\lambda_t)^jB_t]$$

- Doesn't need to buy-back/reissue the entire stock. Only buy-backs/issues difference in payments at each maturity

Market Structure

- Gov't enters time t with payments due to the lenders. Payments are indexed by (B_t, λ_t)
  - Government selects (B_{t+1}, λ_{t+1}) taking as given price schedules for zero coupon bonds maturing in j periods $\{q_{j,t}\}_j$
- Timing of events in debt market as in Cole and Kehoe (2000):
  - Shocks s_t are realized
  - Gov't chooses (B_{t+1}, λ_{t+1}) ▸ Examples
  - Lenders pick price for bonds maturing at $t + j$, $\forall\, j$: $\{q_{j,t}\}_j$
  - Gov't decides whether to default ($\delta_t = 0$) or not ($\delta_t = 1$)
- In the event of a default:
  - Gov't gets outside option, $\underline{V}(s_{1,t})$
  - Holders of legacy and newly issued debt get no repayment

Recursive Equilibrium

- Let $\mathbf{S} = (B, \lambda, s)$

- A Recursive Equilibrium is value functions $\{V(.), \underline{V}(.)\}$, gov't choices $\{\delta(.), B'(.), \lambda'(.), G(.)\}$ and a pricing function $\{q(.)\}$ such that

1 The pricing schedule of a zero coupon bond maturing in j periods equals

$$q_j\left(s, B', \lambda'\right) = \delta\left(\mathbf{S}\right) \mathbb{E}\left\{M\left(s_1, s_1'\right) \delta\left(\mathbf{S}'\right) q_{j-1}\left(s', B'', \lambda''\right) |\mathbf{S}\right\} \text{ for } j \geq 1$$

2 The Gov't solves the decision problem

$$V(\mathbf{S}) = \max_{\delta, B', \lambda', G} \left\{\delta\left[U(G) + \beta \mathbb{E}[V(\mathbf{S}')|\mathbf{S}]\right] + (1-\delta)\underline{V}(s_1)\right\}$$

$$G + B \leq Y + \Delta(\mathbf{S}, B', \lambda')$$

$$\Delta(\mathbf{S}, B', \lambda') = \sum_{j=1}^{\infty} q_j(s, B', \lambda')[(1-\lambda')^{j-1} B' - (1-\lambda)^j B]$$

The Logic of Self-Fulfilling Debt Crises

- In certain states, outcomes not fully determined by fundamentals

- We partition the state space into three regions
  - **Default zone**: Gov't always defaults
  - **Safe zone**: Gov't always repays
  - **Crisis zone**: Whether Gov't repays or not depends on lenders' beliefs

The Logic of Self-Fulfilling Debt Crises

- In certain states, outcomes not fully determined by fundamentals
- Indeterminacy of outcomes arises only in the **crisis zone** due to a coordination failure
  - **Good outcome**
    - A lender expects the other lenders to extend credit to the gov't
    - The gov't can rollover the old debt and decides to repay
    - The lender extends credit to the gov't
  - **Bad outcome**
    - A lender expects the other lenders to not extend credit to the gov't
    - The gov't cannot rollover the old debt and decides to default
    - The lender does not extend credit to the gov't

Some Useful Notation

- Notation: let

$$q_j^\star\left(s, B', \lambda'\right) \quad = \quad \mathbb{E}\left\{M\left(s_1, s_1'\right)\delta\left(\mathbf{S}'\right) q_{j-1}\left(\mathbf{S}', B'', \lambda''\right)|\mathbf{S}\right\}$$

be the *no default today* price, and let

$$\Delta^\star(\mathbf{S}, B', \lambda') = \sum_{j=1}^{\infty} q_j^\star(\mathbf{S}, B', \lambda')[(1-\lambda')^{j-1}B' - (1-\lambda)^j B]$$

be the resources the gov't raises from the market at such prices

Default Zone, Safe Zone, and Crisis Zone

- The **default zone** is the set of states ($\mathcal{S}^{\text{def}}$) such that gov't defaults even if lenders expect repayment

$$\max_{B',\lambda'} \left\{ U\left(Y - B + \Delta^{\star}(\mathbf{S}, B', \lambda')\right) + \beta\mathbb{E}[V\left(B', \lambda', s'\right)|\mathbf{S}] \right\} < \underline{V}\left(s_1\right)$$

In default zone, gov't always defaults

- The **safe zone** is the set of states ($\mathcal{S}^{\text{safe}}$) such that gov't repays even if lenders expect default

$$U\left(Y - B\right) + \beta\mathbb{E}[V\left((1-\lambda)B, \lambda, s'\right)|\mathbf{S}] > \underline{V}\left(s_1\right)$$

In safe zone, gov't always repays

- If neither inequalities hold, then we are in the **Crisis zone**. Whether Gov't repays or not depends on lenders' beliefs

Coordination Failures in the Crisis Zone

- Suppose that a lender expects other lenders to post $q_j = q_j^\star, \forall j$
  - By definition of crisis zone, it is optimal for the gov't to repay because

$$\max_{B',\lambda'} \left\{ U\left(Y - B + \Delta^\star(\mathbf{S}, B', \lambda')\right) + \beta \mathbb{E}[V\left(B', \lambda', s'\right) | \mathbf{S}] \right\} \geq \underline{V}\left(s_1\right)$$

  - It is optimal for the lender to post $q_j = q_j^\star$ (she expects the gov't to repay)

- Suppose that a lender expects other lenders to post $q_j = 0, \forall j$
  - By definition of crisis zone, it is optimal for the gov't to default because

$$U\left(Y - B\right) + \beta \mathbb{E}[V\left((1-\lambda)B, \lambda, s'\right) | \mathbf{S}] < \underline{V}\left(s_1\right)$$

  - It is optimal for the lender to post $q_j = 0$ (she expects the gov't to default)

Constructing Stationary Sunspot Equilibria

We resolve this indeterminacy by considering the following selection mechanism:

- Let $\mathcal{S}^{\text{crisis}}$ be the set of states characterizing the crisis zone
- If $\mathbf{S} \in \mathcal{S}^{crisis}$, lenders do not roll-over gov't debt with probability π.
- We allow π to vary over time
- The non-fundamental state variables are $s_2 = (\xi, \pi)$
    - ξ is an indicator that tells us whether lenders do not roll-over Gov't debt *today* if the Gov't is in the Crisis zone $(\xi = 1)$
    - π is the probability that lenders will not roll-over Gov't debt *tomorrow* if the Gov't is in the Crisis zone. We assume π is i.i.d.

Maturity Choices and Sources of Default Risk

Maturity Choices and Sources of Default Risk

Consider interest rate spreads on a bond maturing tomorrow

$$\frac{r_{1,t} - r_t^*}{r_t^*} = \underbrace{\Pr_t\{\mathbf{S}_{t+1} \in \mathcal{S}^{def}\}}_{\text{Pr. of being in default zone}} + \underbrace{\Pr_t\{\mathbf{S}_{t+1} \in \mathcal{S}^{crisis}\}\pi_t}_{\text{Pr. of rollover crisis}} - \underbrace{\text{cov}_t\left(\frac{M_{t,t+1}}{\mathbb{E}_t[M_{t,t+1}]}, \delta_{t+1}\right)}_{\text{Compensation for risk}}$$

- Spreads depend on
  - Probability that the gov't will be in $\mathcal{S}^{\text{def}}$ ("fundamental default")
  - Probability that the gov't will be in $\mathcal{S}^{\text{crisis}}$, and the lenders coordinate on the bad equilibrium ("rollover crisis")
  - Risk premia that lenders demand for holding bonds exposed to default risk

Note: we allow for time-variation in *price of risk* in quantitative analysis

Loosely, we allow for stochastic changes in the risk aversion of lenders

Maturity Choices and Sources of Default Risk

Consider interest rate spreads on a bond maturing tomorrow

$$\frac{r_{1,t} - r_t^*}{r_t^*} = \underbrace{\Pr_t\{\mathbf{S}_{t+1} \in \mathcal{S}^{def}\}}_{\text{Pr. of being in default zone}} + \underbrace{\Pr_t\{\mathbf{S}_{t+1} \in \mathcal{S}^{crisis}\}\pi_t}_{\text{Pr. of rollover crisis}} - \underbrace{\text{cov}_t\left(\frac{M_{t,t+1}}{\mathbb{E}_t[M_{t,t+1}]}, \delta_{t+1}\right)}_{\text{Compensation for risk}}$$

- Fundamental and non-fundamental shocks move spreads by affecting these three components
- Our objective is to isolate the component due to rollover risk

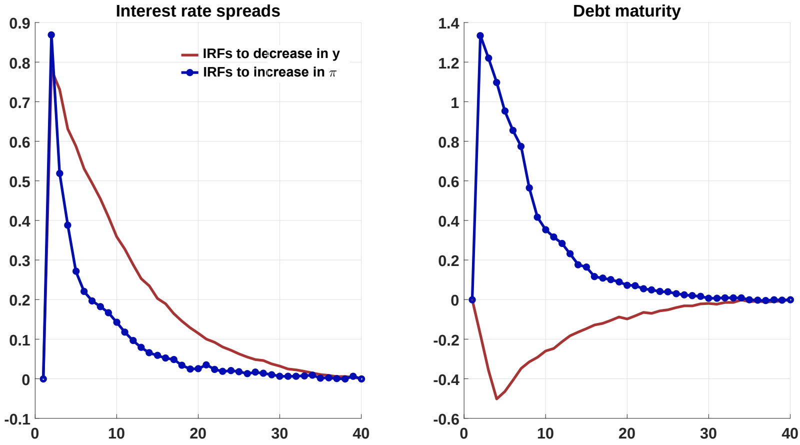
Maturity Choices and Sources of Default Risk

Consider interest rate spreads on a bond maturing tomorrow

$$\frac{r_{1,t} - r_t^*}{r_t^*} = \underbrace{\Pr_t\{\mathbf{S}_{t+1} \in \mathcal{S}^{def}\}}_{\text{Pr. of being in default zone}} + \underbrace{\Pr_t\{\mathbf{S}_{t+1} \in \mathcal{S}^{crisis}\}\pi_t}_{\text{Pr. of rollover crisis}} - \underbrace{\text{cov}_t\left(\frac{M_{t,t+1}}{\mathbb{E}_t[M_{t,t+1}]}, \delta_{t+1}\right)}_{\text{Compensation for risk}}$$

- For this purpose, we will look at the behavior of debt maturity
  - Suppose spreads increase because of an increase in rollover risk (E.g. π_t increases)
    - Gov't has incentives to lengthen debt maturity
  - Suppose spreads increase because of an increase in the probability of a fundamental default (E.g. Y_t decreases while $\pi_t = 0$)
    - Gov't has incentives to shorten debt maturity

Maturity Choices and Sources of Default Risk



- Maturity shortens when probability of fundamental default increases (Y_t decreases while $\pi_t = 0$)
- Maturity lengthens when rollover risk increases (increase in π_t)

Maturity Choices in Absence of Rollover Risk

- Useful to consider first the trade-offs that the government faces when managing debt maturity in absence of rollover risk

- Suppose $\pi = 0$ in all states. In this environment, the debt maturity structure balances two forces

  - Incentive: Short term debt desirable because it disciplines borrowing behavior of future gov't

  - Insurance: Long term debt desirable because it provides insurance to gov't

The Incentive Channel

- Short term debt disciplines the borrowing behavior of future gov't
- Underlying problem: the *future* gov't does not internalize that by borrowing more it increases interest rates that the *current* gov't faces. It borrows "too much"
- If future gov't inherits short term liabilities, less incentives to borrow
  - Interest rates on new issuances of debt increase when the gov't borrows because of heightened default risk
  - If debt is short term, gov't needs to refinance the old stock of debt at higher interest rates
  - If debt is long term, no need to refinance the stock of debt at higher interest rates

The Insurance Channel

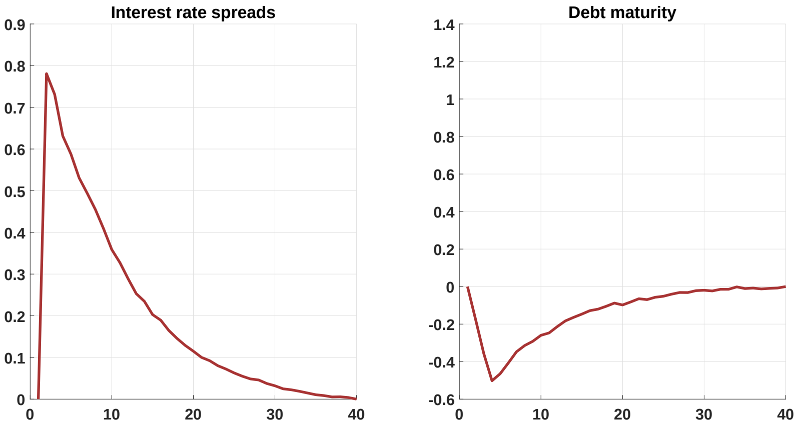
- Long term debt hedges the gov't against tax revenue shocks
  - With long term debt, gov't cut spending less in bad times and more in good times relative to short term debt
- Consider a negative shock to tax revenues
  - Interest rates on new issuances of debt increase because of heightened risk of default
  - If debt is short term, gov't needs to reissue the old stock of debt at the higher interest rates. Need to cut back consumption in bad times
  - If debt is long term, no need to refinance the entire old stock at higher rates. Less need to cut back consumption in bad times

Maturity Shortens when Fundamentals Worsen

After a negative shock to tax revenues

- Incentive channel ⇒ Short term debt *more* desirable
  - In bad times, gov't wishes to raise resources from lenders in order to smooth consumption
  - Higher benefits of restraining borrowing behavior of future gov't
- Insurance channel ⇒ Short term debt *more* desirable (Dovis, 2014)
  - Pricing schedule are more sensitive to shocks when tax revenues are low
  - Less need of having long maturity structure for hedging purposes because prices become more volatile

Maturity Shortens when Fundamentals Worsen



With Rollover Risk, Three Forces Drive Debt Maturity

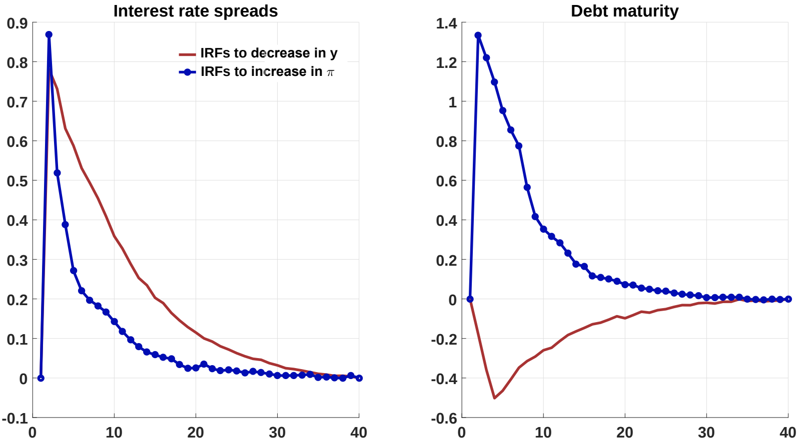
Back to the model with rollover risk. There are now three forces that drive debt maturity

- Incentive: as before
- Insurance: as before
- Avoid crisis zone: Long term debt desirable. It increases $\Pr_t\{\mathbf{S}_{t+1} \in \mathcal{S}^{safe}\}$
  - Lengthen maturity holding face value constant: $B' \downarrow$, $\lambda' \downarrow$
  - Lower payments coming due next period
  - Set of shocks for which inequality is satisfied gets larger

$$U\left(Y' - B'\right) + \beta \mathbb{E}\left[V\left((1-\lambda')B', \lambda', s''\right) \middle| \mathbf{S}'\right] \geq \underline{V}\left(s'\right)$$

When π_t increases, gov't lengthens debt maturity

Maturity Choices and Sources of Default Risk



Measurement strategy: indirectly infer rollover risk from the joint behavior of interest rate spreads and debt maturity

Italy in the 1980s

Quantitative Analysis

Allowing for Time-Variation in the Price of Risk

- Why we allow for shocks to stochastic discount factor $M_{t,t+1}$
  - Risk premia on long term debt increase during crises (Broner et al., 2013)
  - Incentive to shorten debt maturity
- Fit $M_{t,t+1}$ to the term structure of non-defaultable bonds
  - Want to isolate changes in price of risk from changes in default probabilities
  - Fit to the German term structure
    - Free of default risk
    - Assume some holders of German debt also holders of Italian debt
- Our model of term structure is very simple. As robustness we
  - Treat price of risk on long term debt as a primitive, and ask how sizable it must be for the sunspot view to be consistent with data

▸ Small vs. Large Economy

Quantitative Strategy

Two sets of parameters, $\theta = [\theta_1, \theta_2]$

- θ_1 parametrizes stochastic discount factor $M_{t,t+1}$
- θ_2 parametrizes $\{U(.), \underline{V}(.), f_Y(.|Y), \mu_\pi(.)\}$

Model parametrized in two steps

1. Choose θ_1 to match excess returns on non-defaultable bonds
2. Choose θ_2 to match public finance statistics in Italy

Lenders' Stochastic Discount Factor

Affine term structure model with time-varying price of risk governed by χ_t

- $M_{t,t+1} = \exp\{m_{t,t+1}\}$ given by

$$\begin{aligned} m_{t,t+1} &= -(\phi_0 - \phi_1 \chi_t) - \frac{1}{2}\kappa_t^2 \sigma_\chi^2 - \kappa_t \varepsilon_{\chi,t+1}, \\ \chi_{t+1} &= \mu_\chi (1 - \rho_\chi) + \rho_\chi \chi_t + \sigma_\chi \varepsilon_{\chi,t+1}, \quad \varepsilon_{\chi,t+1} \sim N(0, \sigma_\chi^2) \\ \kappa_t &= \kappa_0 + \kappa_1 \chi_t \end{aligned}$$

- Model implies: expected excess return on n period non-defaultable ZCB

$$\mathbb{E}_t[rx_{t+1}^n] = A_n(\theta_1) + B_n(\theta_1)\chi_t$$

- Choose θ_1 to fit $\mathbb{E}_t[\widehat{rx}_{t+1}^{20}]$ measured by applying Cochrane and Piazzesi (2005) regressions to German ZCBs (1973:Q1-2013:Q4)

- χ_t can be measured from term structure of ZCBs

Government Decision Problem

- Government flow utility: $U(G_t) = \frac{(G_t - \underline{G})^{1-\sigma} - 1}{1-\sigma}$
- Costs of adjusting maturity: $\alpha \left(\frac{1}{4\lambda'} - \overline{d}\right)^2$
- Country's tax revenues are $Y_t = \tau \exp\{y_t\}$, with y_t following

$$y_{t+1} = \mu_y(1-\rho_y) + \rho_y y_t + \sigma_y \varepsilon_{y,t+1} + \sigma_{y\chi}\varepsilon_{\chi,t+1}$$

- Payoff if government defaults:
  - Output losses $d_t = \max\{0, d_0 \exp\{y_t\} + d_1 \exp\{y_t\}^2\}, \quad d_1 > 0$
  - Regain access to capital markets next period with probability ψ
- Process for $\{\pi_t\}$: $\frac{\exp\{\hat{\pi}_t\}}{1+\exp\{\hat{\pi}_t\}}$ with $\hat{\pi}_{t+1} = \pi^* + \sigma_\pi \varepsilon_{\pi,t+1}$

Parametrization of θ_2

- Most parameters $(\underline{G}, \sigma, \tau, F_y(.|y), \psi)$ pinned down by direct observations

- $[\beta, d_0, d_1, \alpha, \overline{d}, \pi^\star, \sigma_\pi]$ simultaneously chosen to match moments

  1 Level and cyclicality of debt-to-output ratio

  2 Moments of the interest rate spreads distribution

  3 Level and volatility of debt maturity

  4 Adjusted R^2 of the following regression

$$\text{spr}_t = a + \mathbf{b}'\mathbf{X}_t + e_t,$$

  where $\mathbf{X}_t$ contains observable state variables and their interactions

Regression
Parameters

Moment Matching

Statistic	Data	Model
Average debt-to-output ratio	88.38	81.58
Correlation deficit and output	-0.25	-0.19
Average spread	0.59	0.96
Stdev of spread	1.16	1.68
Skewness of spread	2.53	8.52
Average debt maturity	6.81	6.79
Stdev of debt maturity	0.16	0.29
Adj. R^2 of regression	0.82	0.61

- Model trajectories broadly consistent with the data
- High and countercyclical debt-to-output ratio
- High discount factor and non-homothetic preferences key for model fit

Elasticities

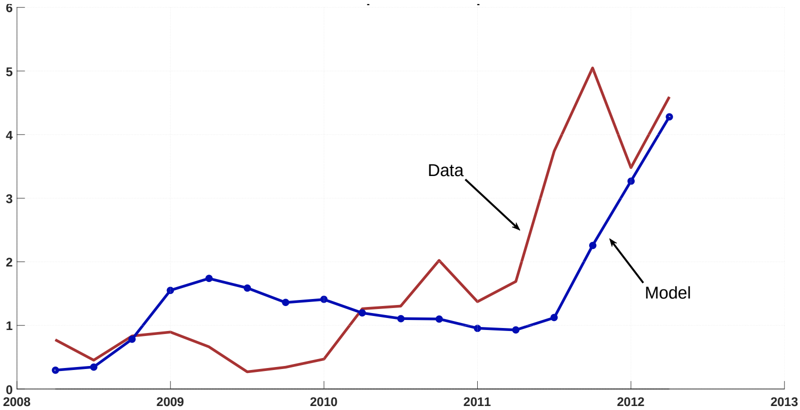
Decomposing Interest Rate Spreads

Decomposing Interest Rate Spreads

Counterfactual on 2008:Q1-2012:Q2 period

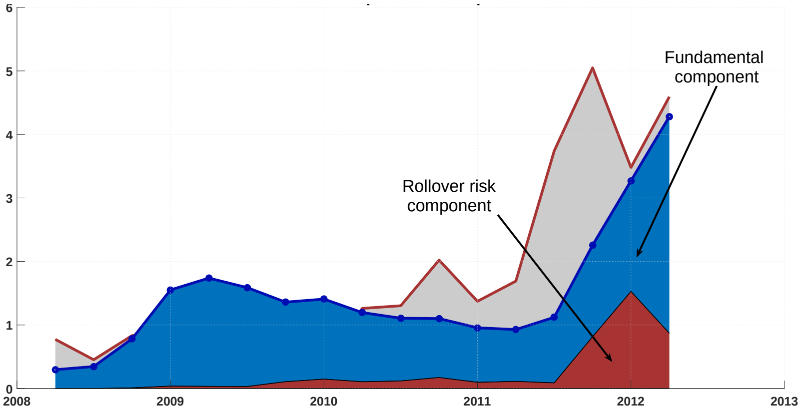
1. Observables: $\mathbf{Y}_t = \left[y_t, \hat{\chi}_t, \text{wal}_t^{\text{it}}, r_{20,t}^{\text{it}} - r_{20,t}^{\text{ger}}\right]$
   - $\text{wal}_{i,t}$ is the weighted average life of interest and coupon payments: $1/\lambda$
2. Conditional on $\mathbf{Y}^t$, use model to filter historical sequence of shocks
   - y_t and $\hat{\chi}_t$ disciplined by actual observations
   - π_t is unobservable
3. Decomposition
   - **Residual component**: Actual less model implied spread
   - **Fundamental risk component**: Counterfactual spread ($\pi_t = 0$)
   - **Rollover risk component**: Model implied spread less counterfactual

Spreads: Model and Data



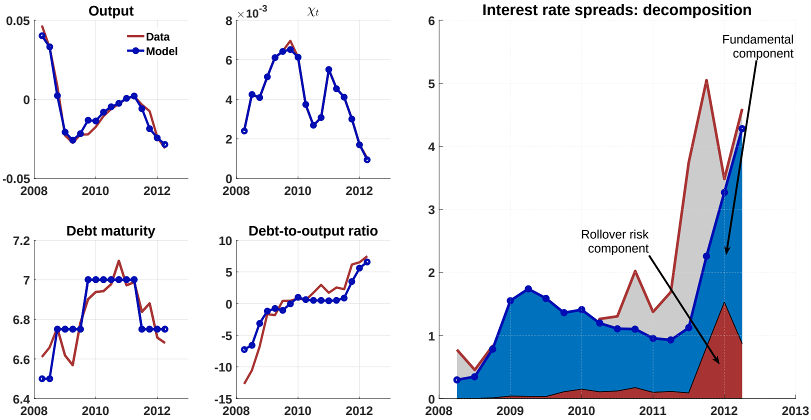
Model cannot account for sharp increase in spread during 2011

Spreads: Model Decomposition



Rollover risk component accounts for 12% of interest rate spreads

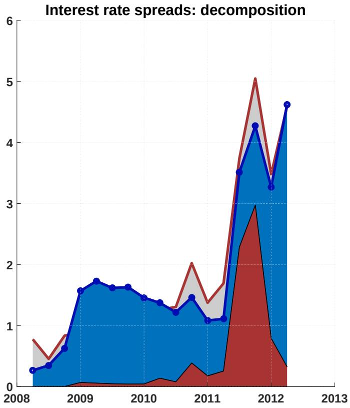
The Role of GDP, Debt and Maturity

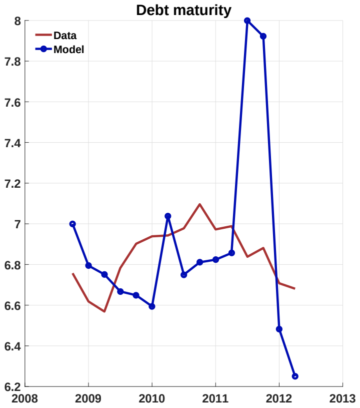


- Low output and high debt ⇒ high fundamental risk
- Debt maturity declines over 2011-2012 ⇒ model attributes little weight to rollover risk

The Information Content of Maturity Choices

We repeat the experiment excluding $\mathrm{wal}_t^{\mathrm{ita}}$ from the set of observables





- Rollover risk is a “residual", used to fit unexplained variation in spreads
- However, it has counterfactual implications for debt maturity

Alternative SDF

ECB Bond Purchasing Program

OMT Short

Evaluating ECB policies

- We have conducted our analysis until 2012:Q2
- In the third quarter of 2012, the ECB announced the establishment of the Outright Monetary Transaction program (OMT)
  - In case a country asks for assistance, the ECB can conduct purchases of sovereign bonds in secondary market
  - Purchases are conducted in full discretion, and without quantitative limits
  - Strict conditionality attached to the program
- After the announcement, spreads in peripheral countries declined substantially, even in absence of actual bond purchases
- A common interpretation is that OMT operated as lending of last resort, eliminating bad equilibria. We can use our framework to test hypothesis

OMT as a price floor

- Central Bank (CB) policy rule: $q_{CB}(\mathbf{S}, B', \lambda'|\lambda)$ and $\bar{B}_{CB}(\mathbf{S}|\lambda)$
- If Gov't asks for assistance:
  - CB buys bonds in secondary markets at price $q_{CB}(\mathbf{S}, B', \lambda'|\lambda)$
  - CB intervention is conditional on the government issuing bonds (B', λ') such that $B' \leq \bar{B}_{CB}(\mathbf{S}|\lambda')$
  - Intervention financed via lump-sum tax on lenders

Can OMT eliminate rollover risk?

Proposition (Normative benchmark)

- $\{q_{CB}, \bar{B}_{CB}\}$ *can be chosen such that the fundamental equilibrium is uniquely implemented*
- *CB assistance is never activated on the equilibrium path*
- *Pareto improvement relative to the private equilibrium*

Example: Let "$*$" denote fundamental equilibrium. Suppose CB sets $\bar{q}_{CB}(\mathbf{S}, B', \lambda'|\lambda) = q^*(\mathbf{S}, B')$ and $\bar{B}_{CB}(\mathbf{S}|\lambda^{*'}(\mathbf{S})) = B^{*'}(\mathbf{S})$

- Lenders willing to pay at least $q_{CB}(\mathbf{s}, B')$ for Gov't bonds
- Government does not default

Interpreting OMT Announcements

Suppose ECB followed normative benchmark. Then $q^{\text{post-OMT}}(.) \leq q^*(.)$

- $q^*(.)$ upper-bound for post OMT price under ECB assumed policy
- We can use the model to compute it

	Actual spreads	**Fundamental spreads**
2012:Q3	354.13	386.76
2012:Q4	285.03	386.97

- If all OMT did was eliminating rollover risk, spreads should have been 386 basis points
- In the data, spreads are below that. Model suggests OMT operated partly via alternative channels (E.g. raising bailout expectations)

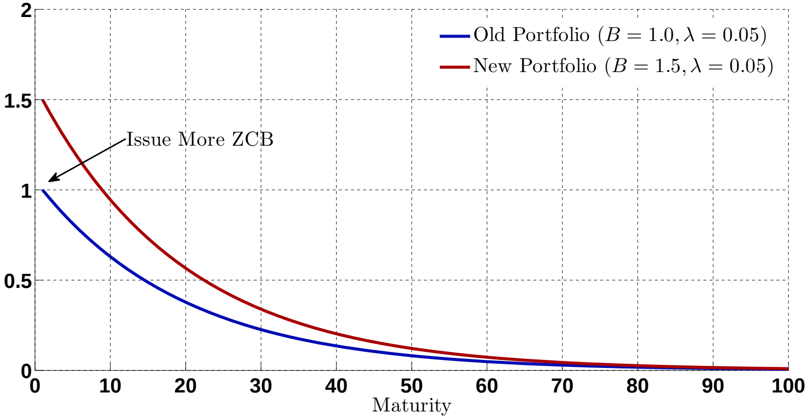
Conclusion

- Measuring sources of default risk important to interpret policies
- Maturity choices around debt crises informative
- Quantitative analysis
  - Rollover risk limited role during the event
  - Lack of discipline on rollover risk without maturity choices
- Measure spreads-reduction due to elimination of rollover risk by OMT
- Similar approach could be applied to study runs on financial institutions

Supplementary Material

Example 1

Increase Face Value keeping duration constant

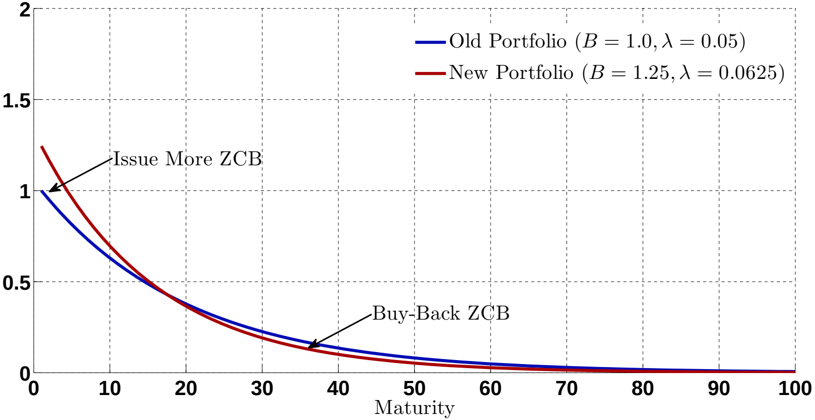


Issues more ZCB at every maturity

Return

Example 2

Shortens duration keeping face value constant



Need some buy-back to shorten duration of portfolio

Return

Italy in the Early 1980s

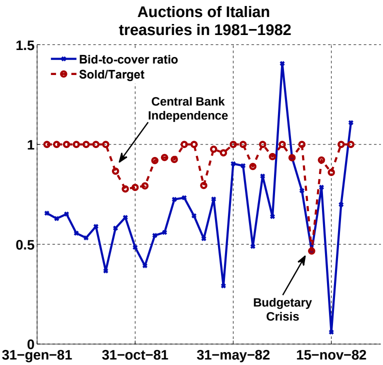
Two factors contributed to raise rollover risk in Italy during the 1980s

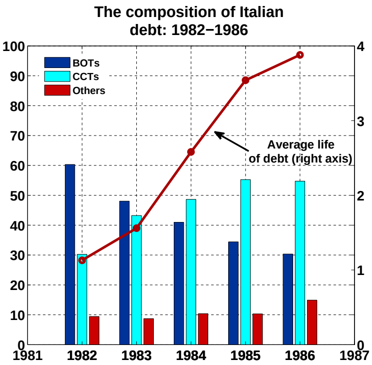
- Extremely low maturity of public debt
  - Average term to maturity went from 7 years in 1970 to 1.13 years in 1981
- July 1981, independence of Bank of Italy (BoI)
  - BoI not obliged anymore to buy unsold government debt in auctions

Treasury needed to rely mostly on private markets for refinancing its debt

- Markets not well developed and volatile at that time

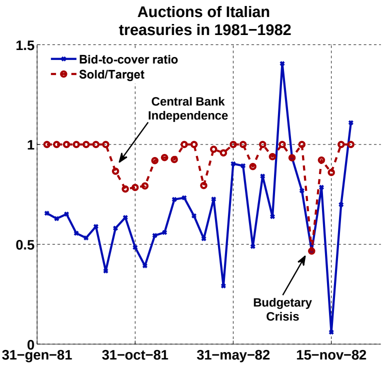
Rollover Risk and Public Debt Management

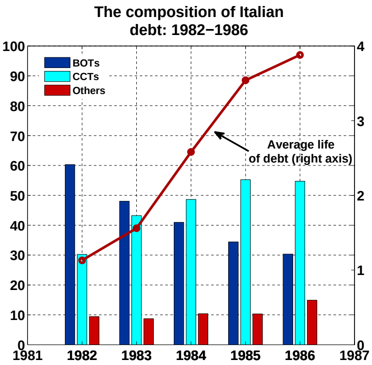




- End of 1982: Treasury department not able to close the budget (hit limit on overdraft account with Bank of Italy)
- Fears of default led to deserted auctions

Rollover Risk and Public Debt Management

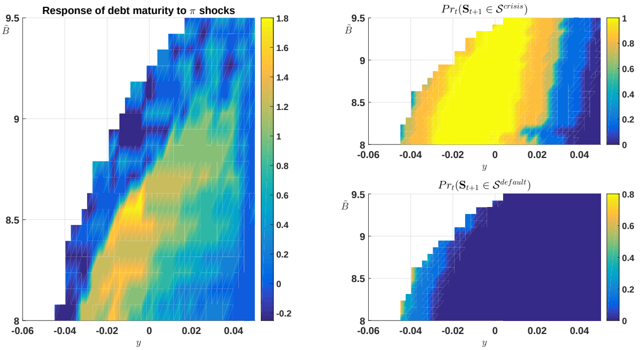




- Introduce new type of bonds (CCTs) with (i) implicit protection for inflation risk, and (ii) longer maturity
- Treasury able to extend debt maturity with this strategy

Return

Response of debt maturity to π across the state space



- State dependence in the IRFs
- Maturity more responsive when government far from default region (when rollover risk sizable)

Return

Small vs. Large Economy

- Assumed lenders' stochastic discount factor is exogenous to Italian default
- Alternative view: Italy is a large economy, a default has negative repercussion on lenders
  - Hence, sunspot indirectly affects lenders' stochastic discount factor

$$\pi_t \uparrow \Rightarrow \ \Pr_t(\delta_{t+1} = 0) \uparrow \Rightarrow \ \text{price of risk} \uparrow$$

- We are sympathetic to this view (computationally challenging though)
- However, we expect our results to hold in such framework too
  - Gov't has even more incentives to lengthen. By avoiding the crisis zone
    - It reduces the risk of a rollover crisis (as in our model)
    - It also reduces the price of risk charged by lenders
  - In the data, maturity shortened

Return

Parametrization of θ_1

Quarterly German data on bond yields (1973:Q1-2013:Q4). Cochrane and Piazzesi (2005) methodology to measure bond risk premia

- First stage regression:

$$\bar{rx}_{t+1} = \gamma_0 + \gamma' \mathbf{f}'_t + \bar{\eta}_t$$

- Second stage regression:

$$rx^{20}_{t+1} = a_{20} + b_{20}(\hat{\gamma}_0 + \hat{\gamma}' \mathbf{f}_t) + \eta^{20}_t$$

Choose θ_1 so that:

- Mean and standard deviation of short term rate in model matches data
- Model matches coefficients of an AR(1) estimated on $\hat{\gamma}_0 + \hat{\gamma}' \mathbf{f}_t$
- Model implied coefficients $(a_{20}, b_{20}, \sigma_{\eta^{20}})$ equal estimates

C-P Regressions Return

Yields and Holding Periods Returns on German Bonds

	Mean	Standard deviation	Sharpe Ratio
$y_t^1 - \text{infl}_t$	2.16	1.93	
$y_t^{20} - \text{infl}_t$	2.94	1.72	
rx_{t+1}^4	0.21	2.05	0.11
rx_{t+1}^8	0.94	4.22	0.22
rx_{t+1}^{12}	1.54	6.08	0.25
rx_{t+1}^{16}	2.02	7.70	0.26
rx_{t+1}^{20}	2.40	9.14	0.26

- Average holding period returns increase with n
- Sharpe ratio increases with n

Return

Cochrane and Piazzesi (2005) regressions

	γ_0	γ_1	γ_2	γ_3	γ_4	γ_5	γ_6	R^2
First Stage	-0.002	-1.65	5.00	-21.70	47.20	-45.18	16.53	0.12
	(-0.27)	(-2.89)	(2.92)	(-2.10)	(1.58)	(-1.19)	(0.95)	

		a_n	b_n	R^2
Second Stage	4	-0.001	0.46	0.20
		(-2.06)	(5.48)	
	8	-0.000	0.77	0.13
		(-0.37)	(4.92)	
	12	0.000	1.02	0.11
		(0.14)	(4.60)	
	16	0.001	1.27	0.11
		(0.30)	(4.55)	
	20	0.001	1.48	0.11
		(0.34)	(4.56)	

- Average holding period returns increase with n
- b_n increases with $n \rightarrow$ Expected excess returns increase with χ_t

Return

Regression

	Specification		
	(1)	(2)	(3)
gdp_t	-0.58	0.25	0.25
	(-3.17)	(1.34)	(0.93)
$debt_t$		0.86	0.76
		(3.43)	(2.186)
χ_t			-0.01
			(-0.06)
$gdp_t \times debt_t$		-0.56	-0.58
		(-6.63)	(-7.88)
$gdp_t \times \chi_t$			0.12
			(0.86)
$debt_t \times \chi_t$			-0.14
			(-0.83)
Sample period	2000:Q1-2012:Q2	2000:Q1-2012:Q2	2000:Q1-2012:Q2
R^2	0.24	0.64	0.68

Most of explanatory power due to output, debt, and their interaction

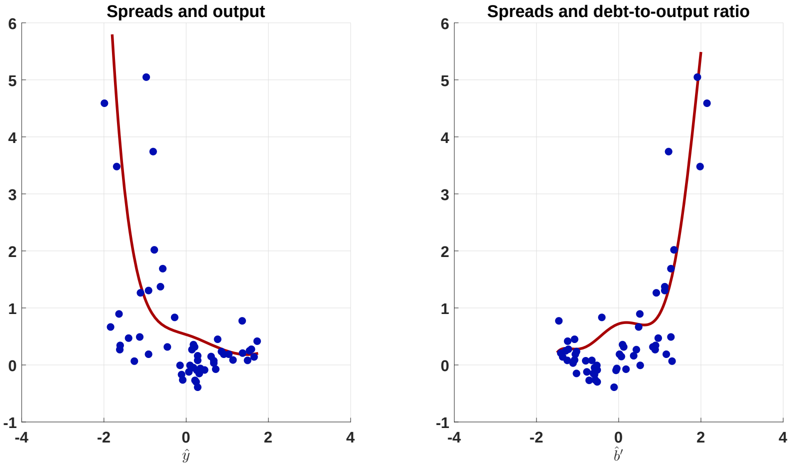
Return

Model Parameters

Parameter	Value	Targets
ϕ_0	0.002	Mean of risk-free rate
ϕ_1	1.473	Standard deviation of risk-free rate
$\kappa_0 \times \sigma_\chi$	-0.053	Method of Simulated Moments
$\kappa_1 \times \sigma_\chi$	-95.125	Method of Simulated Moments
μ_χ	0.002	Method of Simulated Moments
ρ_χ	0.449	Method of Simulated Moments
σ_χ	0.003	Method of Simulated Moments
Panel B: Government's decision problem		
σ	2.00	Conventional value
ψ	0.050	Cruces and Trebesh (2011)
τ	0.410	Tax revenues over GDP
$\underline{G}$	0.680	Non discretionary spending over tax revenues
μ_y	0.892	Normalization
ρ_y	0.970	Estimates of output process
σ_y	0.008	Estimates of output process
$\sigma_{y\chi}$	-0.002	Estimates of output process
$\frac{\exp\{\pi^*\}}{1+\exp\{\pi^*\}} \times 400$	1.628	Method of Simulated Moments
σ_π	1.350	Method of Simulated Moments
β	0.970	Method of Simulated Moments
d_0	0.045	Method of Simulated Moments
d_1	0.082	Method of Simulated Moments
α	0.400	Method of Simulated Moments
$\bar{d}$	6.750	Method of Simulated Moments

Return

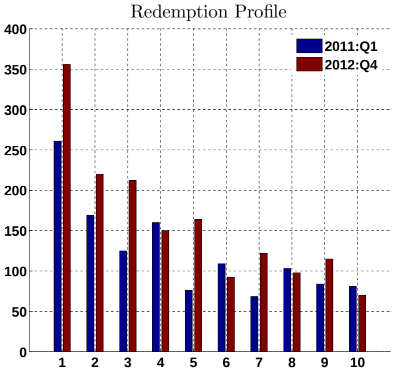
Model Fit: Spreads, Output and Debt

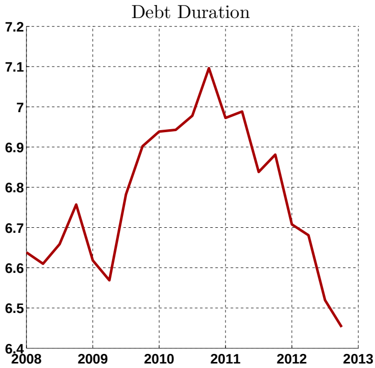


Return

Debt Maturity

We use Treasury data to construct redemption profiles





- Between 2011-2012, the amount due within three years increased by 233 billions euros ($\approx$ 13% of annual GDP)
- Weighted average life declined by 10% (from 7.1 to 6.45 years)

Return

Information on Counterfactual

We can express $\mathbf{Y}_t = \left[y_t, \hat{\chi}_t, \text{wal}_t^{\text{it}}, r_{20,t}^{\text{it}} - r_{20,t}^{\text{ger}} \right]$ as

$$\begin{aligned} \mathbf{Y}_t &= \mathbf{g}(\mathbf{S}_t; \theta) + \eta_t \qquad \eta_t \sim \mathcal{N}(0, \Sigma) \\ \mathbf{S}_t &= \mathbf{f}(\mathbf{S}_{t-1}, \varepsilon_t), \end{aligned}$$

By applying the particle filter we obtain $\{p(\mathbf{S}_t | \mathbf{Y}^t)\}_{t=2008:Q1}^{2012:Q2}$

Specifics:

- Initialization: we initialize $\{B_0, \pi_0\}$ at the ergodic mean. $\{\lambda_0, y_0, \chi_0\}$ at their observed value
- Measurement errors: We set the variance of measurement errors on $\{y_t, \chi_t, \text{wal}_t^{\text{it}}\}$ to 1% of their sample variance, 5% for $\{r_{20,t}^{\text{it}} - r_{20,t}^{\text{ger}}\}$.

▸ Return

An Alternative Discount Factor for Lenders

- Let

$$q_n\left(\mathbf{S}, B', \lambda'\right) = \delta(\mathbf{S}) \frac{M}{1 + \alpha_n M} \mathbb{E}\left[\delta(\mathbf{S}') q'_{n-1}\right]$$

- The expected return for holding this bond equals

$$\frac{\mathbb{E}[\delta(\mathbf{S}') q'_{n-1} | \mathbf{S}]}{q_n(\mathbf{S}, B', \lambda')} = \frac{1}{M} + \alpha_n,$$

  α_n measures expected excess return on bond maturing in n-periods

- Parametrize $\{\alpha_n\}$ such that if maturity of debt portfolio increases by one year, expected excess returns of portfolio increase by $\gamma_1\%$

- What value of γ_1 eliminates gains of lengthening due to rollover risk?

Gains from Lengthening when Rollover Risk Sizable

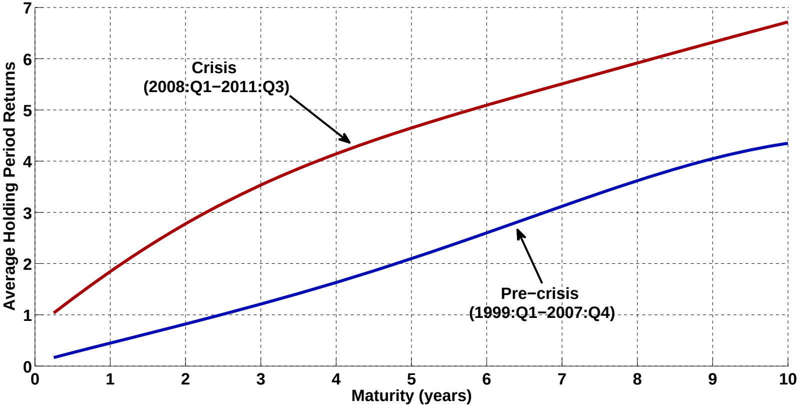
- Select $(\mathbf{S}, \lambda', B')$ such that model replicates observables in Italy in 2011:Q4 and rollover risk component of spreads maximized
- Compute certainty equivalent consumption for different values of λ'

	Maturity of debt portfolio		
	5.5 years	6.7 years	8 years
$\gamma_1 = 0.00\%$	0.9192	0.9178	0.9222
$\gamma_1 = 0.50\%$	0.9119	0.9111	0.9174
$\gamma_1 = 1.00\%$	0.9059	0.9054	0.9075
$\gamma_1 = 1.50\%$	0.9034	0.9025	0.9055
$\gamma_1 = 1.75\%$	0.9040	0.9006	0.8967

γ_1 needs to be at least 1.75% to make the Gov't willing to shorten maturity

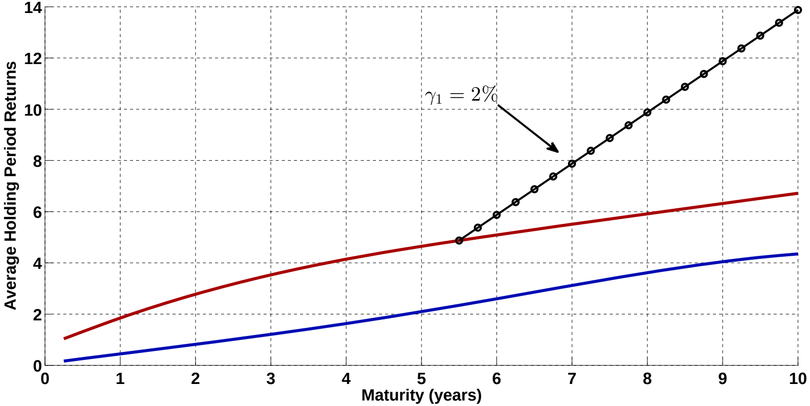
Is $\gamma_1 \geq 1.75\%$ Empirically Plausible?

Compute average holding period returns on Italian bonds by maturity



They increase with maturity, more during the crisis

Is $\gamma_1 \geq 1.75\%$ Empirically Plausible?



However, $\gamma_1 \geq 1.75\%$ far from being empirically plausible

Return

Evaluating ECB policies

- We have conducted our analysis until 2012:Q2
- In the third quarter of 2012, the ECB announced the establishment of the Outright Monetary Transaction program (OMT)
    - In case a country asks for assistance, the ECB can conduct purchases of sovereign bonds in secondary market
    - Purchases are conducted in full discretion, and without quantitative limits
    - Strict conditionality attached to the program
- After the announcement, spreads in peripheral countries declined substantially, even in absence of actual bond purchases
- A common interpretation is that OMT operated as lending of last resort, eliminating bad equilibria. We can use our framework to test hypothesis

Interpreting OMT Announcements

- We model OMT as price floor and quantity controls, and show that the Central Bank can use these instruments to eliminate bad equilibria
- If the Central Bank follows this policy, bond spreads should jump to their *fundamental value* (E.g. prices in absence of the rollover problem)
- We can use the model to compute these fundamental spreads

	Actual spreads	**Fundamental spreads**
2012:Q3	354.13	386.76
2012:Q4	285.03	386.97

- If all OMT did was eliminating rollover risk, spreads should have been 386 basis points
- In the data, spreads are below that. Model suggests OMT operated partly via alternative channels (E.g. raising bailout expectations)