Long-Term Debt Pricing and Monetary Policy Transmission under Imperfect Knowledge

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The views expressed are those of the authors and are not necessarily reflective of views at the Federal Reserve Bank of New York or the Federal Reserve System

Motivation

- Macroeconomic models depend on household and firm expectations
- Policy design
  - Not enough to observe some history of beliefs
  - Need a theory of the determination of beliefs: rational expectations
- Rational expectations policy design
  - Heavy reliance on managing expectations through announced commitments
  - What are the consequences of imprecise control of beliefs?

Motivation II

- For example, Bernanke (2004):

> "[...] most private-sector borrowing and investment decisions depend not on the funds rate but on longer-term yields, such as mortgage rates and corporate bond rates, and on the prices of long-lived assets, such as housing and equities. Moreover, the link between these longer-term yields and asset prices and the current setting of the federal funds rate can be quite loose at times."

The Agenda

- Simple model of output gap and inflation determination
- One informational friction:
  - Agents have an incomplete knowledge about the economy
- Explore constraints imposed on stabilization policy by financial market expectations
  - What if the expectations hypothesis of the yield curve does not hold?
  - Is the zero lower bound on nominal interest rates an important constraint?

Asset Structure and the Fiscal Authority

- Exogenous purchases of G_t per period

- Issue two kinds of debt
  - B_t^s: One period debt in zero net supply with price $P_t^s = (1 + i_t)^{-1}$
  - B_t^m: An asset in positive supply that has the payoff structure

$$\rho^{T-(t+1)} \text{ for } T \geq t + 1$$

- Let P_t^m denote the price of this second asset. Asset has the properties:
  - Price in period $t + 1$ of debt issued in period t is ρP_{t+1}^m
  - Average maturity of the debt is $(1 - \beta\rho)^{-1}$

Asset Pricing: Theory I

- Log-linear approximation of Euler equations for each kind of bond holdings implies

$$\hat{\imath}_t = -\hat{P}_t^s = -\hat{E}_t^i \left(\hat{P}_t^m - \rho\beta \hat{P}_{t+1}^m \right)$$

  - Restriction on asset price movements
  - Combined with transversality

$$\hat{P}_t^m = -\hat{E}_t \sum_{T=t}^{\infty} (\rho\beta)^{T-t} \hat{\imath}_T$$

  - Asset price is a function of fundamentals: the expectations hypothesis of the term structure holds; does not imply interest-rate expectations consistent with monetary policy strategy
  - Call: Anchored Financial Market Expectations

Optimal Spending Plans I

- Assume agents understand fiscal policy is Ricardian

- When the expectations hypothesis of the term structure holds — aggregate demand relation of the form

$$\begin{aligned}\hat{C}_t^i &= -\hat{E}_t^i \sum_{T=t}^{\infty} \beta^{T-t} \left[\beta \left(i_T - \pi_{T+1}\right)\right] \\ &\quad + \bar{s}_C^{-1} \left(1-\beta\right) \hat{E}_t^i \sum_{T=t}^{\infty} \beta^{T-t} \left[\left(\frac{\bar{\theta}-1}{\bar{\theta}}\right)\left(1+\gamma^{-1}\right)\hat{w}_T + \bar{\theta}^{-1}\hat{\Gamma}_T\right]\end{aligned} \tag{1}$$

  - Example of permanent income theory

  - Independent of the average maturity structure of debt; Isomorphic to an economy with one-period debt — i.e. $\rho = 0$

  - Independent on long-debt-price expectations

Asset Pricing: Theory II

- Under non-rational expectations and incomplete markets: exist alternative ways to impose no-arbitrage

- Consider pricing the asset directly

$$\hat{\imath}_t = -\hat{E}_t^i \left(\hat{P}_t^m - \rho\beta \hat{P}_{t+1}^m \right)$$

  in all periods t

  - Given monetary policy and expectations, asset price determined. No-arbitrage consistent forecasts of the short-rate can then be determined by

$$\hat{E}_t^i \hat{\imath}_T = -\hat{E}_t^i \left(\hat{P}_T^m - \rho\beta \hat{P}_{T+1}^m \right)$$

  - Because interest rate projections are not directly related to current interest rates — expectations hypothesis need not hold

- Demand then determined by

$$\begin{aligned}\hat{C}_t^i &= -\hat{E}_t^i \sum_{T=t}^{\infty} \beta^{T-t} \left[\beta \left(\left(\rho\beta \hat{P}_{T+1}^m - \hat{P}_T^m\right) - \pi_{T+1}\right)\right] \\ &\quad + \bar{s}_C^{-1} (1-\beta) \hat{E}_t^i \sum_{T=t}^{\infty} \beta^{T-t} \left[\left(\frac{\bar{\theta}-1}{\bar{\theta}}\right)\left(1+\gamma^{-1}\right)\hat{w}_T + \bar{\theta}^{-1}\hat{\Gamma}_T\right]\end{aligned} \tag{2}$$

  - Nest anchored expectations model when $\rho = 0$; since $\hat{E}_t^i \hat{\imath}_T = -\hat{E}_t^i \hat{P}_T$
  - In this case forecasting bond prices and forecasting interest rates equivalent
    - As maturity increases this divergence increases

Beliefs Formation

- Agents construct forecasts according to

$$\hat{E}_t^i X_{t+T} = a_{t-1}^X$$

where $X = \left\{\pi, \hat{w}, \hat{\Gamma}, \hat{\imath}, \hat{P}^m\right\}$ for any $T > 0$.

  - In period t forecasts are predetermined.
  - Beliefs are updated according to the constant gain algorithm

$$a_t^X = (1 - g)\, a_{t-1}^X + g X_t$$

    where $g > 0$
  - With i.i.d. shocks and zero debt nests the REE
    - Learning only about the constant

Beliefs Formation II

- Under anchored expectations, based on interest-rate data:

$$\hat{E}_t^i \hat{\imath}_T = a_{t-1}^i$$

- Under unanchored expectations, based on bond-price data:

$$\begin{aligned} \hat{E}_t \hat{\imath}_T &= -\hat{E}_t \left(\hat{P}_T^m - \rho\beta \hat{P}_{T+1}^m \right) \\ &= -\left(1 - \rho\beta\right) a_{t-1}^{P^m} \end{aligned}$$

  - In general they are not equal
  - Equivalent when $\rho = 0$

Calibration

- Discount factor is $\beta = 0.99$
- Labor supply elasticity $\gamma^{-1} = 2$
- Nominal rigidities $\alpha = 0.75$
- Elasticity of demand across differentiated goods $\bar{\theta} = 8$

Unanchored Expectations and Simple Rules

- Consider the case of a simple Taylor rule

$$\hat{\imath}_t = \phi_\pi \hat{\pi}_t + \phi_y x_t$$

- Use notion of "robust stability"
  - Dynamics converge for a given gain coefficient
  - Distinct from E-stability

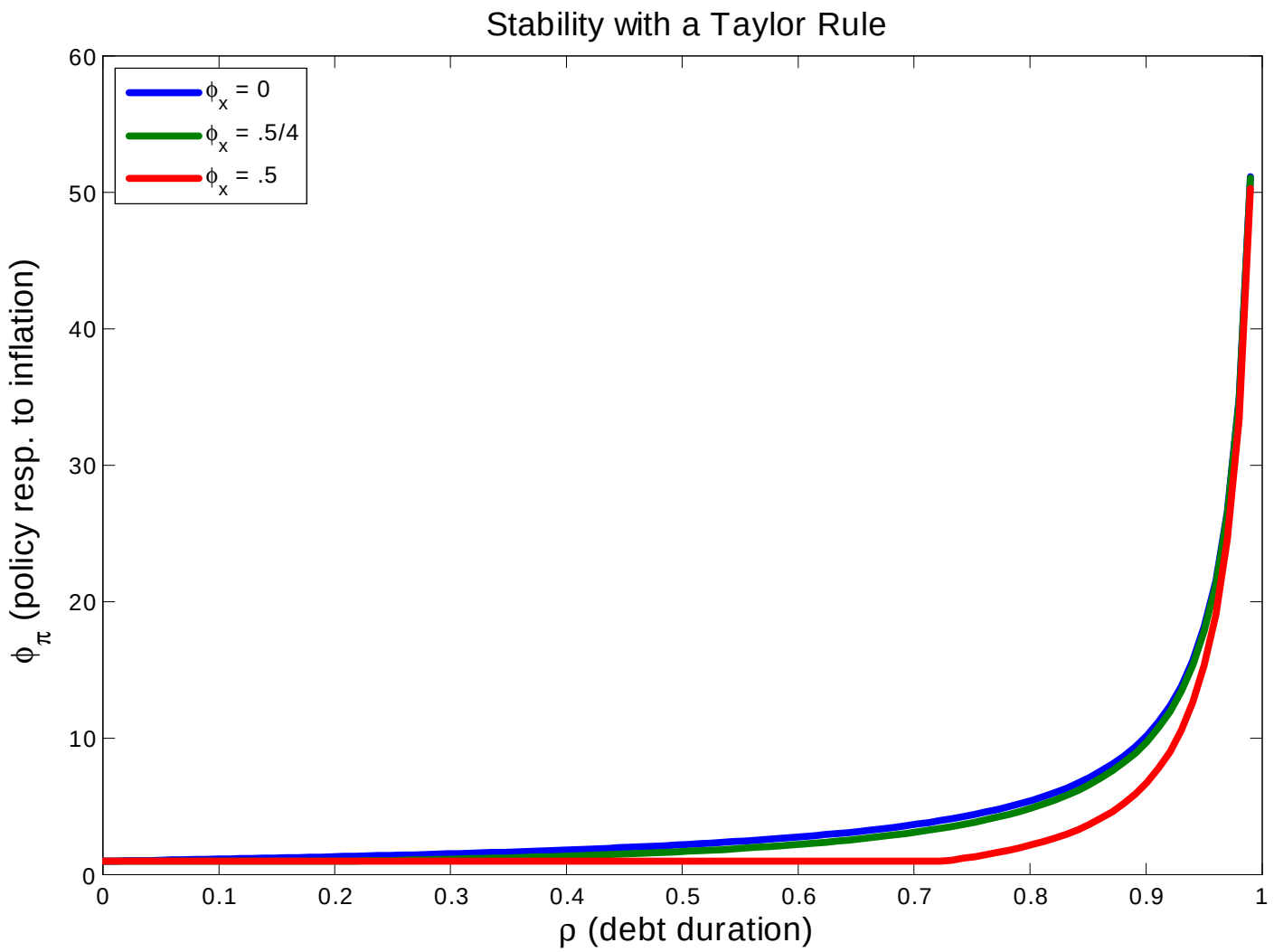


Figure 1: Robust stability regions for different maturity structures. The three contours correspond to different Taylor distinguished by their respond to the current output gap.

Intuition

- Aggregate demand can be written

$$\begin{aligned} x_t &= -\hat{\imath}_t + \hat{E}_t \rho\beta \hat{P}^m_{t+1} + \hat{E}_t \sum_{T=t}^{\infty} \beta^{T-t} \left[\beta\left(1-\rho\right)\hat{P}^m_{T+1} + \pi_{T+1}\right] - \hat{A}_t \\ &\quad + \bar{s}_C^{-1}\left(1-\beta\right)\hat{E}_t \sum_{T=t}^{\infty} \beta^{T-t}\left[\left(\frac{\bar{\theta}-1}{\bar{\theta}}\right)\left(1+\gamma^{-1}\right)\hat{w}_{T+1} + \bar{\theta}^{-1}\hat{\Gamma}_{T+1}\right]. \end{aligned}$$

  - For infinite-period debt $\rho = 1$: depends only on $\hat{E}_t \hat{P}^m_{t+1}$
  - Requires aggressive adjustment of current nominal interest rates

- Key mechanism: increasing debt maturity implies arbitrage restrictions in the expectations hypothesis are weaker

Optimal Policy under Rational Expectations

- Consider target criterion

$$\pi_t = -\bar{\theta}^{-1} x_t$$

Optimal Policy under Rational Expectations II

- Target criterion approach implies
  - Interest-rate policy sufficiently aggressive to guarantee satisfaction of the target criterion
  - Adjustment of policy in response to asset prices
- Both might be thought to confer stabilization advantages

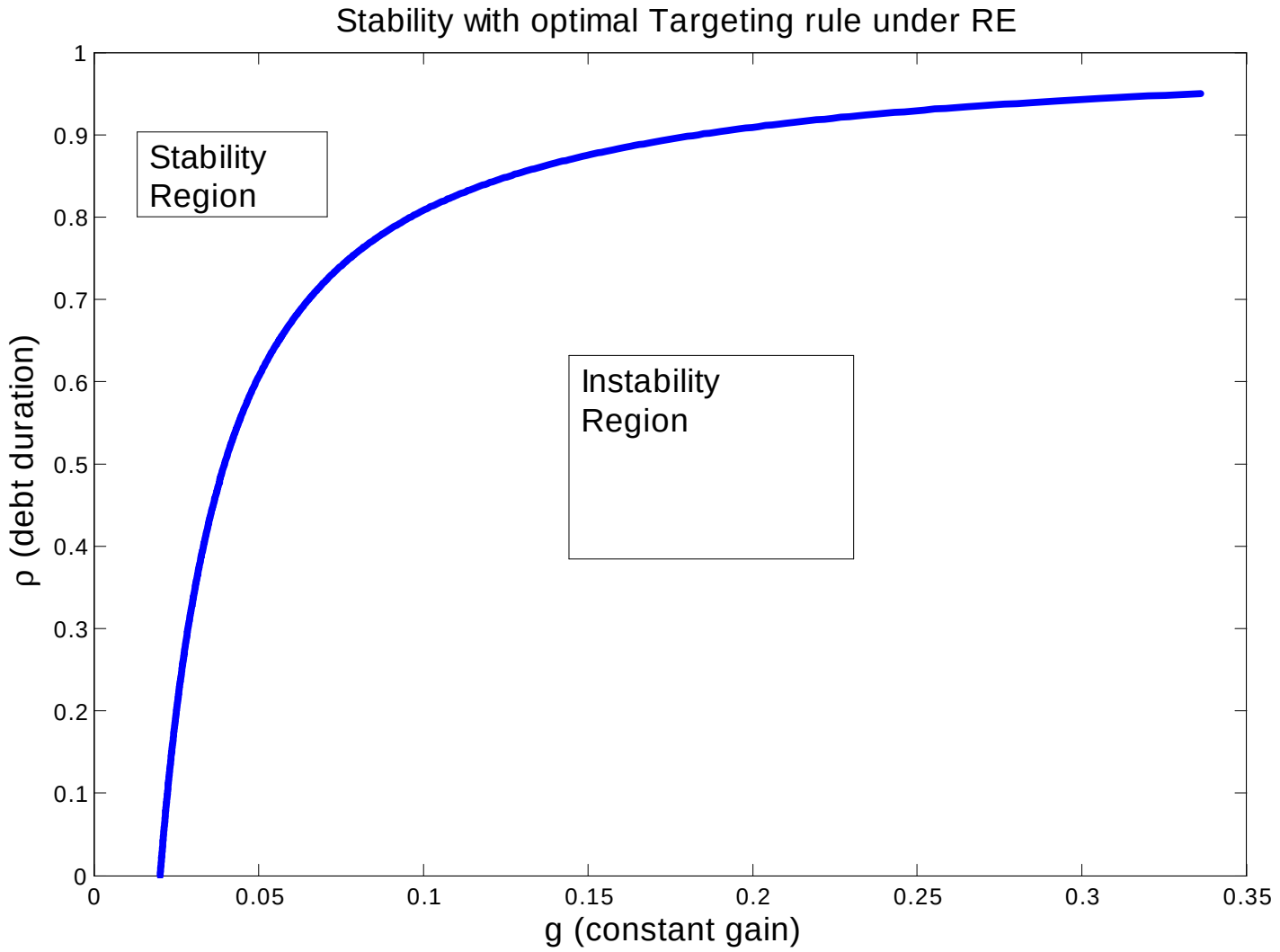


Figure 2: Stability regions in gain-maturity space for the optimal rational expectations target criterion under discretion.

Intuition

- Second distinct mechanism at play
  - For a given average maturity of debt — higher gains imply greater volatility in expectations and therefore require more aggressive adjustment in interest rates which has destabilizing feedback effects
  - As the average maturity rises, arbitrage relationship defining term structure weakens — implies more aggressive policy feasible
- Shifting interest-rate expectations represent an additional constraint on policy
  - Limits scope to react to current macroeconomic developments

Optimal Policy

- Central Bank seeks to minimize

$$\min_{\{x_t,\pi_t,i_t,P_t^m,a_t^\pi,a_t^Y,a_t^w,a_t^\Gamma\}} \bar{E}_0^{RE} \sum_{t=0}^{\infty} \beta^t \left[\pi_t^2 + \lambda_x \left(x_t - x^*\right)^2 + \lambda_i \left(i_t - i^*\right)\right]$$

  where $\lambda_x, \lambda_i \geq 0$ and x_t the output gap and $Y = \{P^m, i\}$. Minimization subject to the constraints:

  - Aggregate demand and supply
  - No-arbitrage equation
  - Beliefs
  - Disturbances: technology and cost-push shocks

Properties of Optimal Policy

Proposition 1 *The first-order conditions representing a solution to the minimization of the loss subject to i) the aggregate demand, supply and arbitrage equations;the no-arbitrage condition; and ii) the law of motion for the beliefs* $a_t^{\pi}, a_t^{Y}, a_t^{w}, a_t^{\Gamma}$ *have a unique bounded rational expectations solution for all parameter values. In particular, model dynamics are unique for all possible gains.*

- First-order conditions constitute a linear rational expectations model
  - Can be solved used standard methods
  - Does not imply that learning is irrelevant for policy outcomes

Special Case: No uncertainty

- Two limiting results of interest
  - When $g \to 0$ and $\beta < 1$ then

$$\lim_{T \to \infty} E_t \pi_T = \frac{\kappa \lambda_x x^*}{\kappa^2 + \lambda_x (1 - \beta)}$$

  - When $g > 0$ and $\beta \to 1$ then

$$\lim_{T \to \infty} E_t \pi_T = 0$$

- Patient Central Banker replicates the optimal commitment policy under rational expectations
  - Price stability is optimal in the long run

Impulse Response Functions: Reintroducing Uncertainty

- Assume $\lambda_i = 0$ and $x^* = i^* = 0$
  - Compare with dynamics under rational expectations
  - Cost-push shock

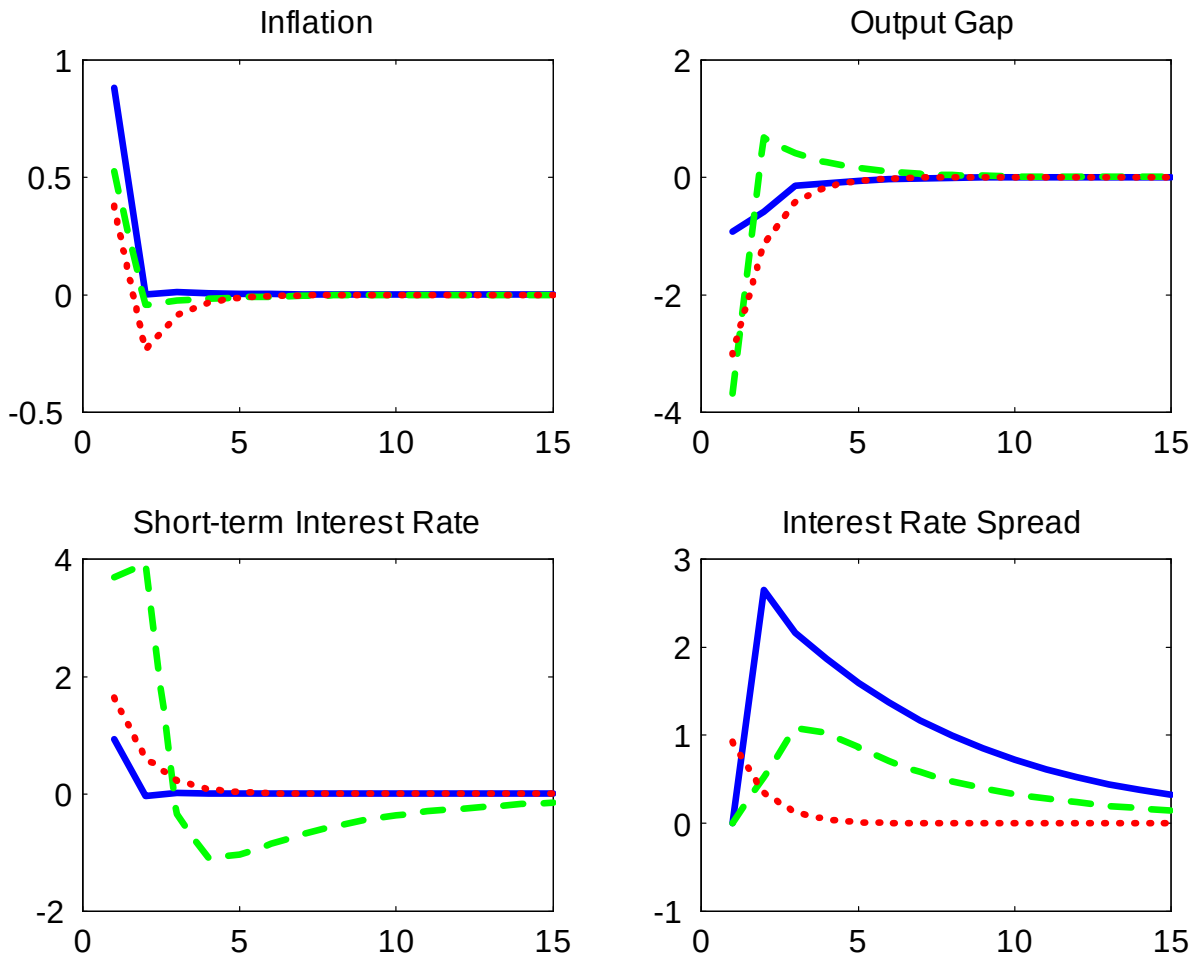


Figure 3: Impulse response functions in response to a cost-push shock. Gain = 0.15. Rational expectations: red dotted line; learning with anchored expectations: blue solid line; and learning with unanchored expectations: green dashed line.

Implications II

- Anchored expectations:
  - Expectations hypothesis holds which imposes a constraint on current interest-rate movements
  - Inflation and output more volatile
- Unanchored expectations:
  - Current interest-rate policy divorced from interest-rate expectations
  - Inflation and output less volatile; interest rates more volatile

Efficient Policy Frontiers

- Compute

$$\bar{L} = V[\pi] + \lambda_x V[x] + \lambda_i V[i]$$

  where $V[\cdot]$ denotes unconditional variance

- Study variation in

$$V[\pi] + \lambda_x V[x]$$

  as tolerated variance in interest-rates varies: that is $V[i]$

  - Equivalent to studying the original loss function as λ_i varies

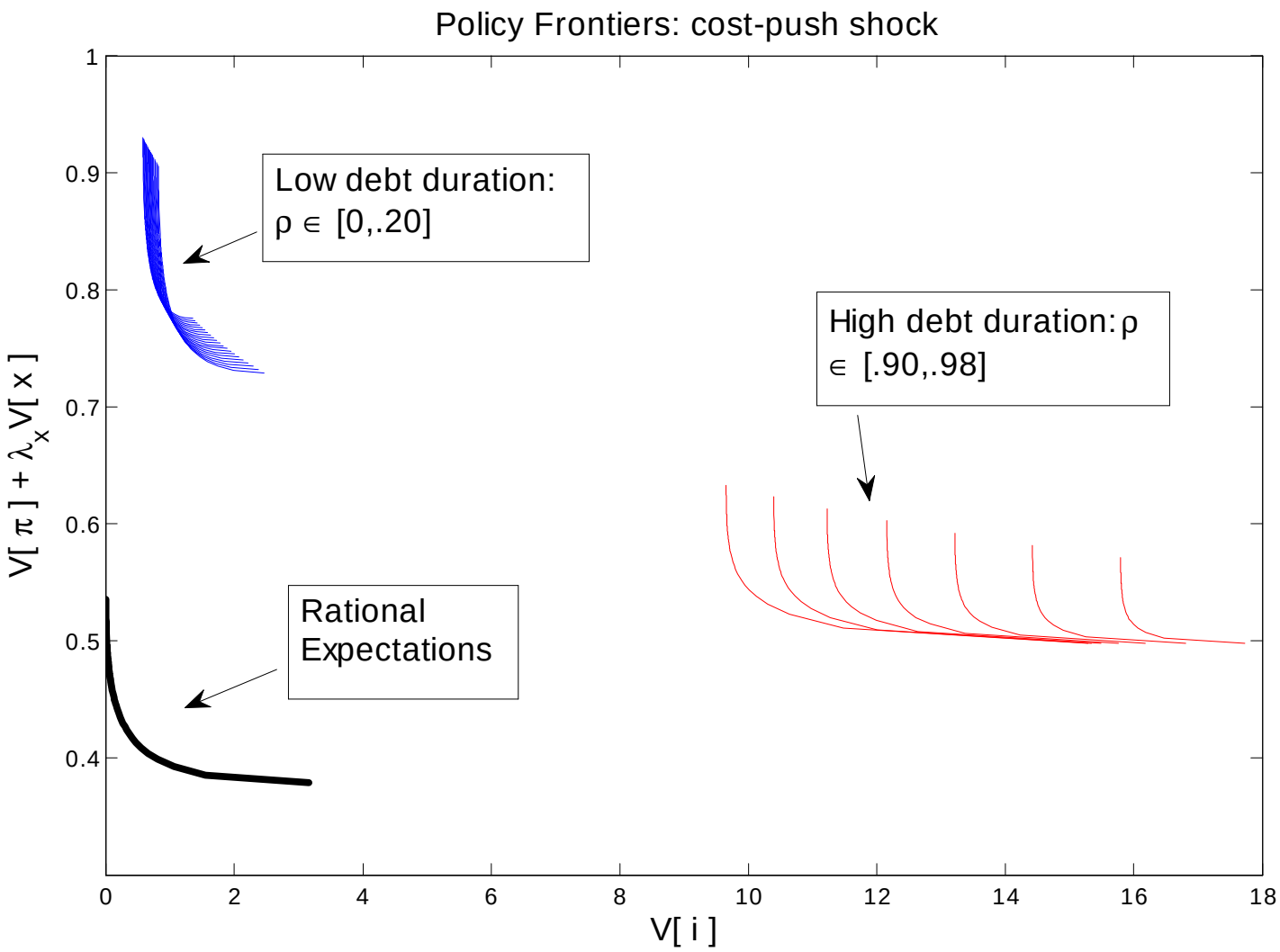


Figure 4: Policy frontiers as weight on interest rate stability is increased. Exogenous disturbance is a cost-push shock.

The Zero Lower Bound on Nominal Interest Rates

- Compute the unconditional probability of being at the zero lower bound in each model

- Requires two additional parameter assumptions.
  - The average level of the short-term nominal interest rate: **5.4%** (annualized),
    - corresponds to the average rate of the US 3-month T-bill for the period 1954Q3-2011Q3
  - Under RE and $\lambda_i = 0.08$ calibrate the volatility of the technology shocks to deliver a standard deviation of output of **1.5%** (in log-deviations from its steady state) and probability of ZLB being 3.5%

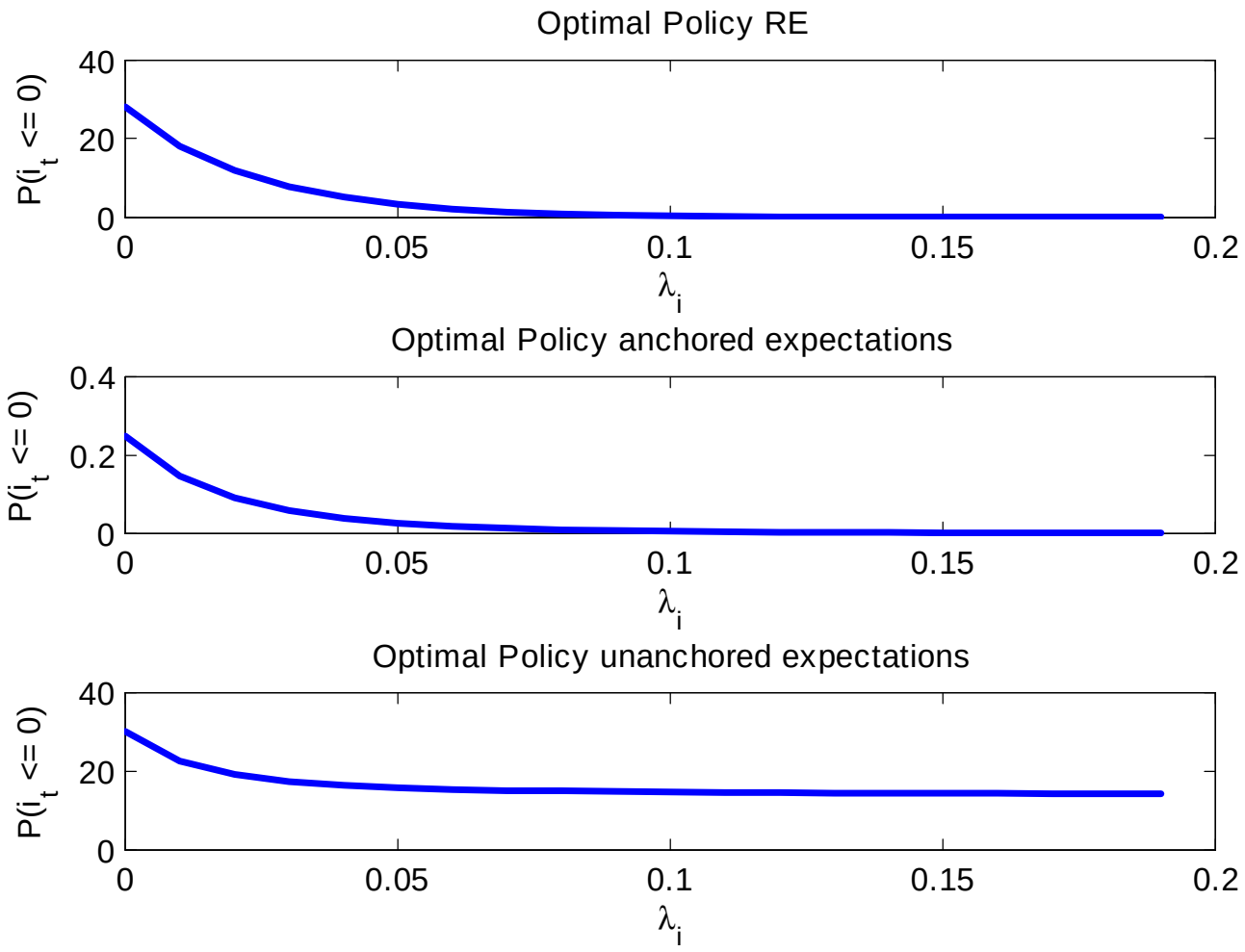


Figure 5: The figure shows the unconditional probability of being at the ZLB as a function of λ_i for the three different models.

Implications

- If financial market expectations unanchored
  - Zero lower bound likely to a relevant constraint on monetary policy
  - True even if substantial weight placed on losses from such variation
- Contrasts markedly with claims that "Zero lower bound on nominal interest rate is of little quantitative relevance in standard New Keynesian models"
  - Chung et. al. 2010, Schmitt-Grohè and Uribe 2007

Conclusion

- Failure of beliefs to satisfy the expectations hypothesis of the term structure limits the efficacy of monetary policy
  - The pricing of public debt places constraints also on optimal monetary policy
  - Can make the zero lower bound constraint on nominal interest rates more severe