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
  - $B^s_t$: One period debt in zero net supply with price $P^s_t = (1 + i_t)^{-1}$
  - $B^m_t$: An asset in positive supply that has the payoff structure
    \[ \rho T^{- (t+1)} \text{ for } T \geq t + 1 \]

- Let $P^m_t$ denote the price of this second asset. Asset has the properties:
  - Price in period $t + 1$ of debt issued in period $t$ is $\rho P^m_{t+1}$
  - Average maturity of the debt is $(1 - \beta \rho)^{-1}$
Log-linear approximation of Euler equations for each kind of bond holdings implies

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

- Restriction on asset price movements

- Combined with transversality

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

- 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

\[
\hat{C}_t^i = -\hat{E}_t^i \sum_{T=t}^{\infty} \beta^{T-t} [\beta (i_T - \pi_{T+1})]
\]

\[
+ \bar{s}_C^{-1} (1 - \beta) \hat{E}_t^i \sum_{T=t}^{\infty} \beta^{T-t} \left[ \left( \frac{\theta - 1}{\theta} \right) (1 + \gamma^{-1}) \hat{w}_T + \bar{\theta}^{-1} \hat{r}_T \right]
\]  (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

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

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

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

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

\[
\hat{C}_t^i = -\hat{E}_t^i \sum_{T=t}^{\infty} \beta^{T-t} \left[ \beta \left( \rho \hat{P}_{T+1}^m - \hat{P}_T^m \right) - \pi_{T+1} \right]
\]

\[
+ \tilde{s}_C^{-1} (1 - \beta) \hat{E}_t^i \sum_{T=t}^{\infty} \beta^{T-t} \left[ \left( \frac{\bar{\theta} - 1}{\bar{\theta}} \right) \left( 1 + \gamma^{-1} \right) \hat{w}_T + \bar{\theta}^{-1} \hat{r}_T \right]
\]

- Nest anchored expectations model when \( \rho = 0 \); since \( \hat{E}_t^i \hat{r}_T = -\hat{E}_t^i \hat{P}_T \)

- 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 \( X = \{ \pi, \hat{w}, \hat{r}, \hat{i}, \hat{P}_m \} \) 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:
  \[ \hat{E}_t^{i^T} = a_t^i \]

- Under unanchored expectations, based on bond-price data:
  \[ \hat{E}_t^{i^T} = -\hat{E}_t \left( \hat{P}_T^m - \rho \beta \hat{P}_{T+1}^m \right) \]
  \[ = -(1 - \rho \beta) a_{t-1}^{pm} \]
  - 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

\[ \hat{\iota}_t = \phi_\pi \hat{\pi}_t + \phi_y x_t \]

- 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

\[ x_t = -\hat{\eta}_t + \hat{E}_t \rho \beta \hat{P}_{t+1}^m + \hat{E}_t \sum_{T=t}^{\infty} \beta^{T-t} \left[ \beta (1 - \rho) \hat{P}_{T+1}^m + \pi_{T+1} \right] - \hat{A}_t \]

\[ + \bar{s}_C^{-1} (1 - \beta) \hat{E}_t \sum_{T=t}^{\infty} \beta^{T-t} \left[ \left( \frac{\bar{\theta} - 1}{\bar{\theta}} \right) (1 + \gamma^{-1}) \hat{w}_{T+1} + \bar{\theta}^{-1} \hat{r}_{T+1} \right] . \]

– For infinite-period debt \( \rho = 1 \): depends only on \( \hat{E}_t \hat{P}_{t+1}^m \)

– 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

\[ \pi_t = -\theta^{-1} x_t \]
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

\[
\min_{\{x_t, \pi_t, i_t, P^m_t, a^\pi_t, a^Y_t, a^w_t, a^\Gamma_t\}} \mathbb{E}_0^{RE} \sum_{t=0}^{\infty} \beta^t \left[ \pi_t^2 + \lambda_x (x_t - x^*)^2 + \lambda_i (i_t - i^*) \right]
\]

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 \( \lambda_i \) 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 $\lambda_i$ 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