Time Consistency and Duration of Government Debt: A Signalling Theory of Quantitative Easing

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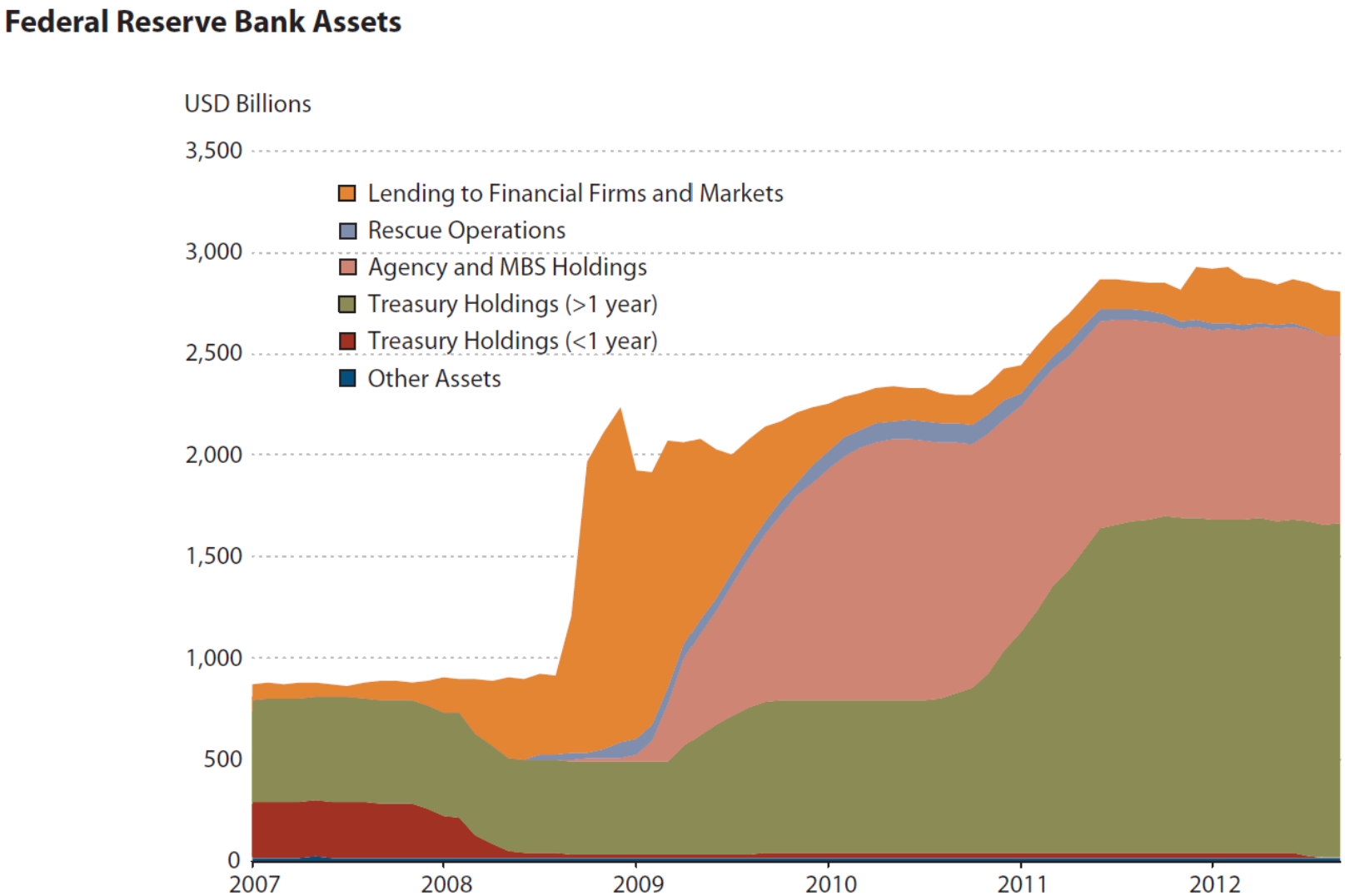
Motivation

- Recently, the Federal Reserve took "unconventional monetary policy" actions
  - One goal of such policy was to reduce long-term interest rates
- Empirical evidence supportive of this effect
  - Gagnon et al (2011), Krishnamurthy and Vissing-Jorgensen (2011), Hamilton and Wu (2012), Swanson and Williams (2013), Bauer and Rudebusch (2013)
- One form of such policy actions was "quantitative easing" (QE)
  - QE involves buying long-term govt debt with money
  - Purchase of long-term bonds: $600 billion in 2010; $667 billion in 2011
- At the ZLB, money and short-term debt are equivalent
  - QE equivalent to reduction in maturity of outstanding govt debt
  - Exchange long-term debt for short-term debt

Motivation


Federal Reserve Bank Assets
USD Billions
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Lending to Financial Firms and Markets
Rescue Operations
Agency and MBS Holdings
Treasury Holdings (>1 year)
Treasury Holdings (<1 year)
Other Assets
2007
2008
2009
2010
2011
2012

Motivation

- QE is neutral in standard models if expectations about the short-term nominal interest rate are unchanged
  - Long rate depends on current and future short rates
  - Wallace (1981), Eggertsson and Woodford (2003)
- Asset-market segmentation is one source of non-neutrality
  - QE decreases risk-premium when assets are imperfect substitutes
  - Chen, Curdia, and Ferrero (2012) and Gertler and Karadi (2013)
- Our paper focuses on a different channel (commitment device)
  - QE affects expectations about future policy
  - It provides a "signal" about low future short-term real interest rates
  - Possibly large effects (reduction of duration by 7 months increases output by 140 bp and inflation by 95.4 bp)?

Private Sector

- Representative household maximizes

$$E_t \sum_{s=0}^{\infty} \beta^s \left[u\left(C_{t+s}\right) + g\left(G_{t+s}\right) - v\left(h_{t+s}\right) \right] \xi_{t+s}$$

st

$$P_t C_t + B_t^S + S_t(\rho) B_t + P_t T_t$$

$$\leq n_t h_t + \left(1 + i_{t-1}\right) B_{t-1}^S + \left(1 + \rho S_t(\rho)\right) B_{t-1} + \int_0^1 Z_t(i) di$$

- Continuum of firms produce differentiated varieties
  - Linear production function $\left(y_t(i) = h_t(i)\right)$
  - Dynamic price-setting problem due to adjustment costs $d\left(\frac{p_t(i)}{p_{t-1}(i)}\right)$

Government Bonds

- Two kinds of govt debt (Woodford (2001))
  - B_t^S : one-period risk-less bond
  - B_t : a perpetuity bond which pays ρ^j dollars $j+1$ periods later (geometrically declining coupons)
- Convenient formulation as do not have to keep track of old bond prices
- Perpetuity bond duration: $\left(1-\beta\rho\right)^{-1}$
  - $\rho = 0$: one-period bond
  - $\rho = 1$: classic consol bond
- Our QE experiment: reduction in ρ

Private Sector Equilibrium

- Two asset-pricing conditions

$$\frac{1}{1+i_t} = E_t\left[\beta \frac{u_C\left(C_{t+1}, \xi_{t+1}\right)}{u_C\left(C_t, \xi_t\right)} \Pi_{t+1}^{-1}\right]; \; i_t \geq 0$$

$$S_t(\rho) = E_t\left[\beta \frac{u_C\left(C_{t+1}, \xi_{t+1}\right)}{u_C\left(C_t, \xi_t\right)} \Pi_{t+1}^{-1}\left(1+\rho S_{t+1}(\rho)\right)\right]$$

- Optimal pricing equation (production subsidy ς)

$$\begin{aligned}
&\varepsilon Y_t\left[\frac{\varepsilon-1}{\varepsilon}\left(1+\varsigma\right) u_C\left(C_t, \xi_t\right) - \tilde{v}_y\left(Y_t, \xi_t\right)\right] \\
&= E_t\left[\beta u_C\left(C_{t+1}, \xi_{t+1}\right) d'\left(\Pi_{t+1}\right) \Pi_{t+1}\right] - u_C\left(C_t, \xi_t\right) d'\left(\Pi_t\right) \Pi_t
\end{aligned}$$

Government

- Output cost of taxation $(s(T_t - T))$ as in Barro (1979)
- Real govt spending and resource constraint

$$F_t = G_t + s(T_t - T)$$
$$Y_t = C_t + F_t + d(\Pi_t)$$

- Govt flow budget constraint

$$B_t^S + S_t(\rho) B_t = (1 + i_{t-1}) B_{t-1}^S + \left(1 + \rho S_t(\rho)\right) B_{t-1} + P_t (F_t - T_t)$$

- Assume $B_t^S = 0; F_t = F$

$$S_t(\rho) b_t = \left(1 + \rho S_t(\rho)\right) b_{t-1} \Pi_t^{-1} + (F - T_t)$$

where $b_t = B_t / P_t$

Time Consistent Equilibrium

- Optimal coordinated monetary and fiscal policy
  - i_t and T_t as policy instruments
- Consolidated govt budget constraint
  - Internalization of fiscal cost of interest rate policy
  - Results from direct central bank balance sheet concerns later
- The govt cannot commit (except for paying back nominal debt) and acts with discretion every period
- Characterize a Markov-perfect Equilibrium (MPE)

Linear-quadratic Approach

- Second-order approximation of household utility around the efficient steady-state (with appropriate production subsidy ς)

$$U_t = -\left[\lambda_\pi \pi_t^2 + \hat{Y}_t^2 + \lambda_T \hat{T}_t^2\right]$$

where $\lambda_\pi \propto d''(.)$ and $\lambda_T \propto s''(.)$

- First-order approximation of private sector equilibrium conditions

$$\hat{Y}_t = E_t \hat{Y}_{t+1} - \sigma(\hat{\imath}_t - E_t \pi_{t+1} - r_t^e);\ \hat{\imath}_t \geq -\left(1-\beta\right) \tag{1}$$

$$\pi_t = \kappa \hat{Y}_t + \beta E_t \pi_{t+1} \tag{2}$$

$$\hat{S}_t = -\hat{\imath}_t + \rho\beta E_t \hat{S}_{t+1} \tag{3}$$

$$\hat{b}_t = \beta^{-1}\hat{b}_{t-1} - \beta^{-1}\pi_t - (1-\rho)\hat{S}_t - \psi \hat{T}_t \tag{4}$$

Linear-quadratic Approach

- Mechanism operates through the govt budget constraint

$$\hat{b}_t = \beta^{-1}\hat{b}_{t-1} - \beta^{-1}\pi_t - (1-\rho)\hat{S}_t - \psi\hat{T}_t$$

- Usual "inflation" incentive due to nominal debt
- "Roll-over" incentive directly affected by ρ
  - Effect of $\hat{\imath}_t$ on $\hat{T}_t$ higher with smaller ρ
- Polar cases
  - $\rho = 0: \ \hat{b}_t = \beta^{-1}\hat{b}_{t-1} - \beta^{-1}\pi_t + \hat{\imath}_t - \psi\hat{T}_t$
  - $\rho = 1: \ \hat{b}_t = \beta^{-1}\hat{b}_{t-1} - \beta^{-1}\pi_t - \psi\hat{T}_t$

Linear-quadratic Approach

- Write the govt's problem recursively

$$V(\hat{b}_{t-1}, r_t^e) = \min_{i_t, T_t} [\lambda_\pi \pi_t^2 + \hat{Y}_t^2 + \lambda_T \hat{T}_t^2 + \beta E_t V(\hat{b}_t, r_{t+1}^e)]$$
$$\text{st } (1)\text{-}(4)$$

- MPE requires that expectations are a function only of $(\hat{b}_{t-1}, r_t^e)$
- Guess a solution to substitute out the expectation functions

$$E_t \pi_{t+1} = \bar{\pi}^E \left(\hat{b}_t, r_t^e\right) = \pi_b \hat{b}_t + \pi_r E_t r_{t+1}^e$$
$$E_t \hat{Y}_{t+1} = \bar{Y}^E \left(\hat{b}_t, r_t^e\right) = Y_b \hat{b}_t + Y_r E_t r_{t+1}^e$$

- After taking FOCs and Envelope condition, match coefficients to verify
- Note, $\hat{r}_t = \hat{\imath}_t - E_t \pi_{t+1} = (i_b - \pi_b b_b) \hat{b}_{t-1} = r_b \hat{b}_{t-1}$
  - Dependence of r_b on ρ critical to the mechanism

Government Optimality Conditions

- Very intuitive govt optimality conditions
- A "targeting rule" that now includes fiscal variables

$$\lambda_\pi \pi_t + \kappa^{-1} \hat{Y}_t = [\kappa^{-1} (1-\rho) \sigma^{-1} + \beta^{-1}] \frac{1}{\psi} \lambda_T \hat{T}_t$$

- A "tax-smoothing" rule

$$\chi \hat{T}_t = -\psi \lambda_T^{-1} \beta \pi_b \kappa^{-1} \hat{Y}_t + E_t \hat{T}_{t+1}$$

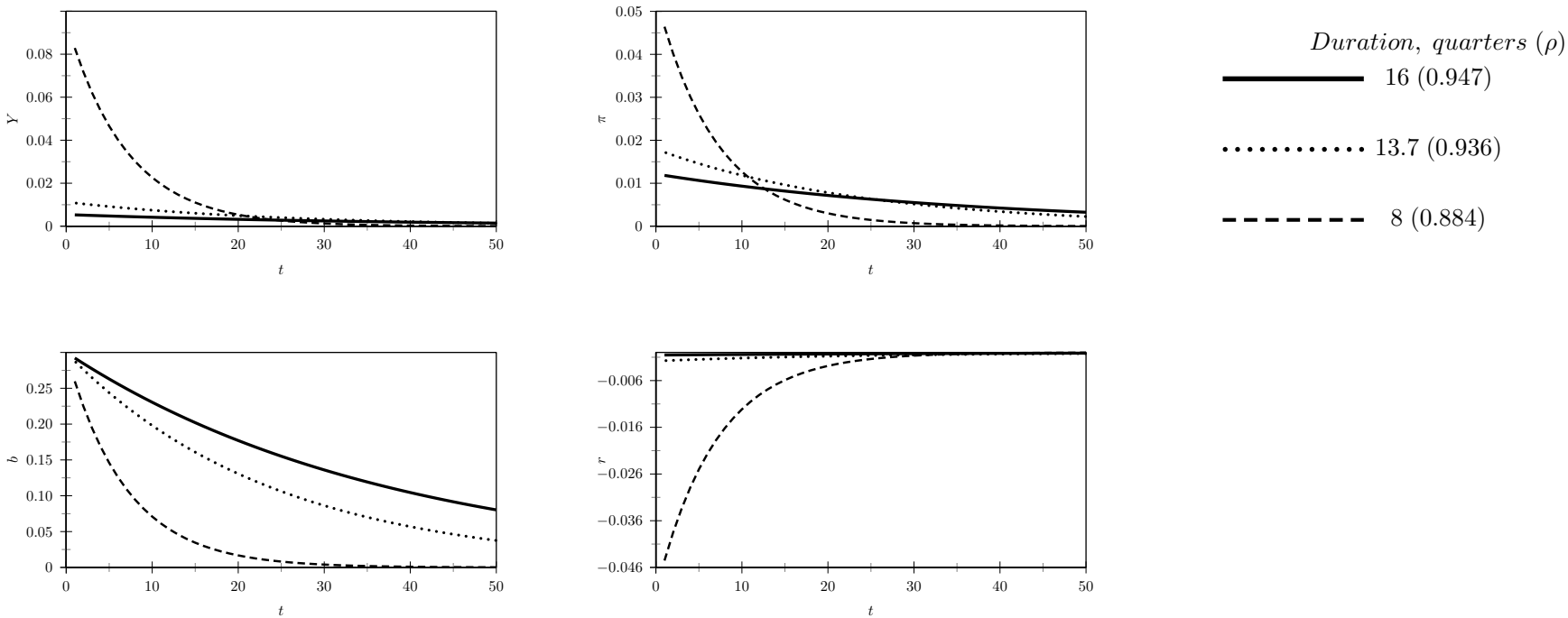
Numerical Analysis

- Pick standard values from the literature for most parameters (Eggertsson (2006))
  - Lowest weight for tax-distortions ($\lambda_T = 0.8$)
  - Use Dallas-Fed (mkt value of debt) and NIIPA (tax revenues) data for $\frac{1}{\psi}$
- Baseline parameterization

Parameter	Value
β	0.99
σ	1
κ	0.02
ε	8
λ_T	0.8
$\frac{1}{\psi}$	7.2

Out of ZLB

IRFs at Different Durations



Responses to a 30% increase in debt outstanding

Inflation Incentives and Duration

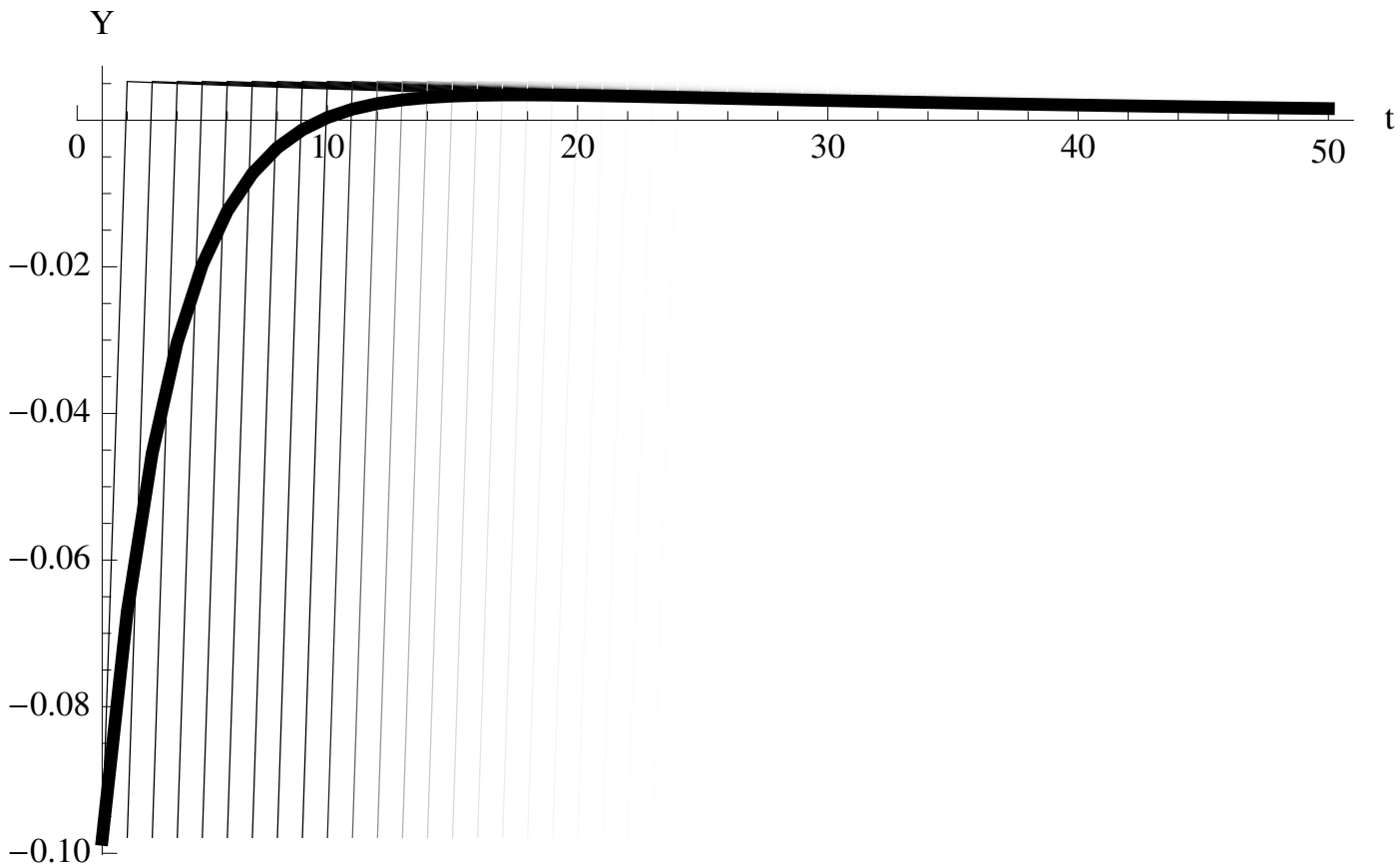
- Reducing duration of debt from 16 to 8 quarters creates the same inflation incentives as
  - Increasing debt from 30% to 120% above steady-state
- Reducing duration of debt thus very effective at generating inflationary expectations in the MPE

ZLB

- A large negative shock to r_t^e makes the ZLB bind
  - Negative "demand" shock
- For computational simplicity, r_t^e follows a two-state Markov process with an absorbing state (Eggertsson and Woodford (2003))
  - Every period, with probability μ, r_t^e takes a value of $-r_L^e$ while with probability $1-\mu$, it goes to steady-state and stays there forever after
- Pick μ and r_L^e such that at the ZLB
  - Drop in output of 10%
  - Drop in inflation of 2% (annualized)
- Initial debt duration: 16 qts (Chadha,Turner,and Zampoli (2013))

ZLB-Output

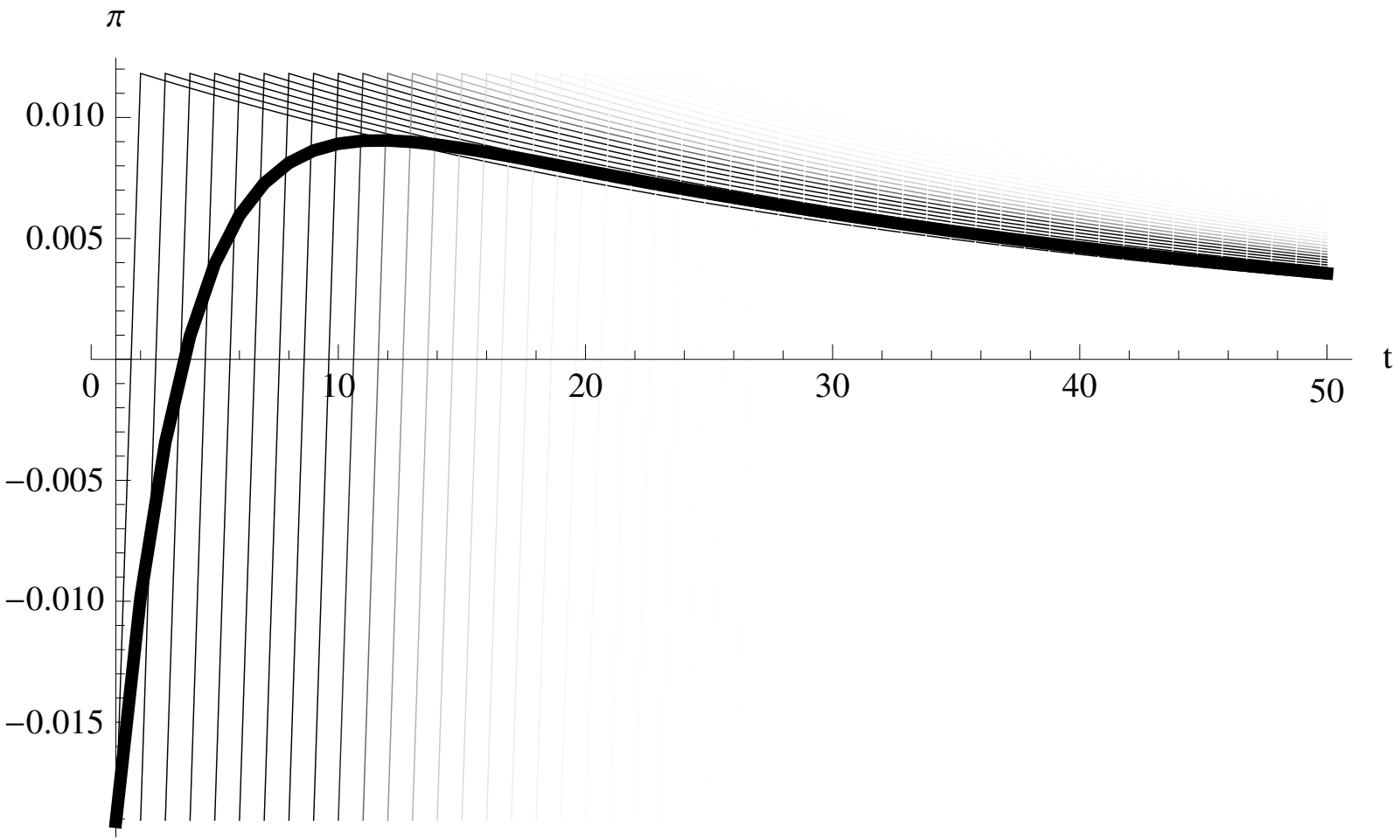
- Output is depressed



Response of output when the duration of debt is 16 quarters

ZLB-Inflation

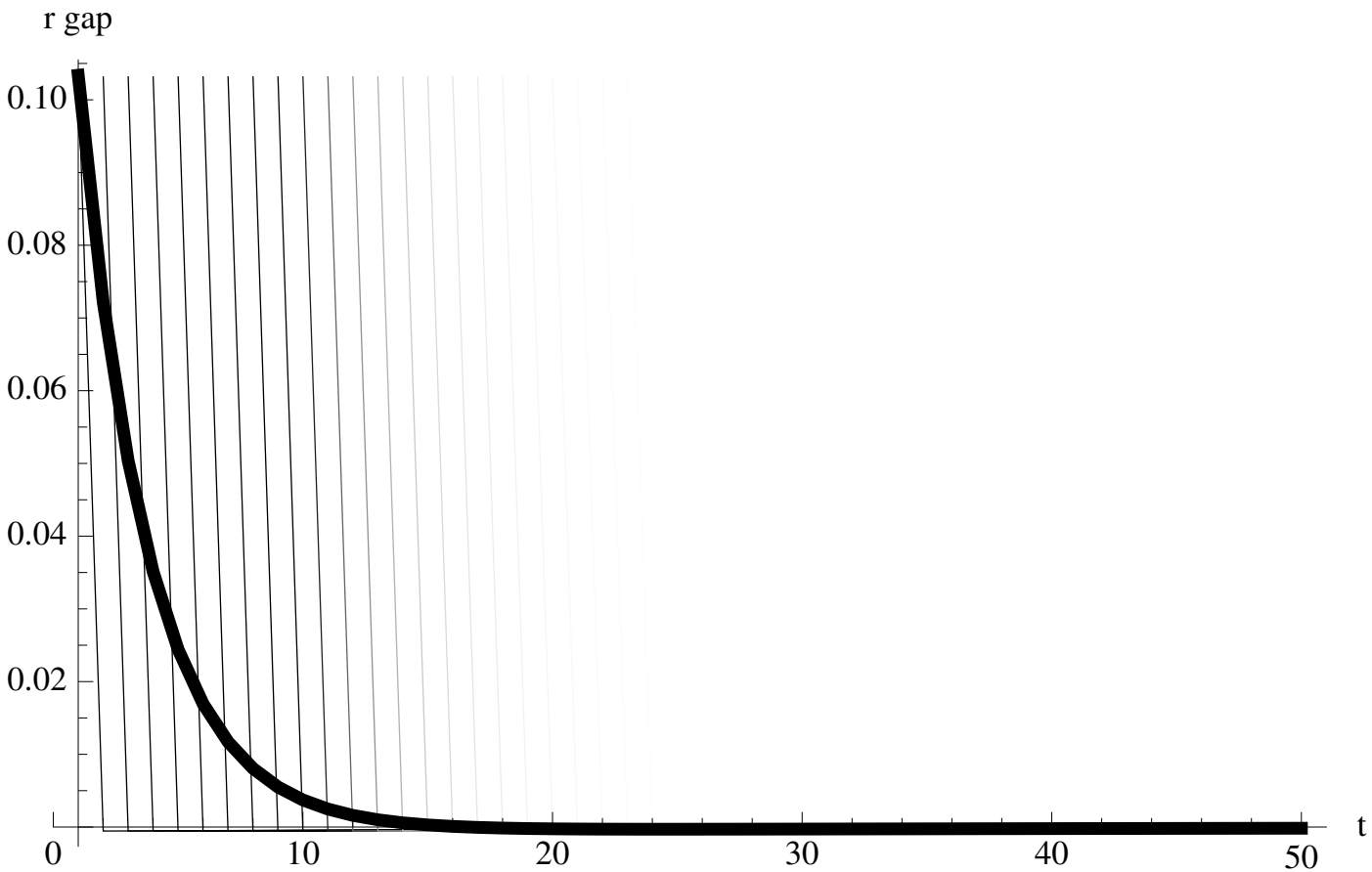
- Economy suffers from deflation



Response of inflation when the duration of debt is 16 quarters

ZLB-Real Interest Rate

- Real interest rate gap $(\hat{r}_t - r_t^e)$ is elevated

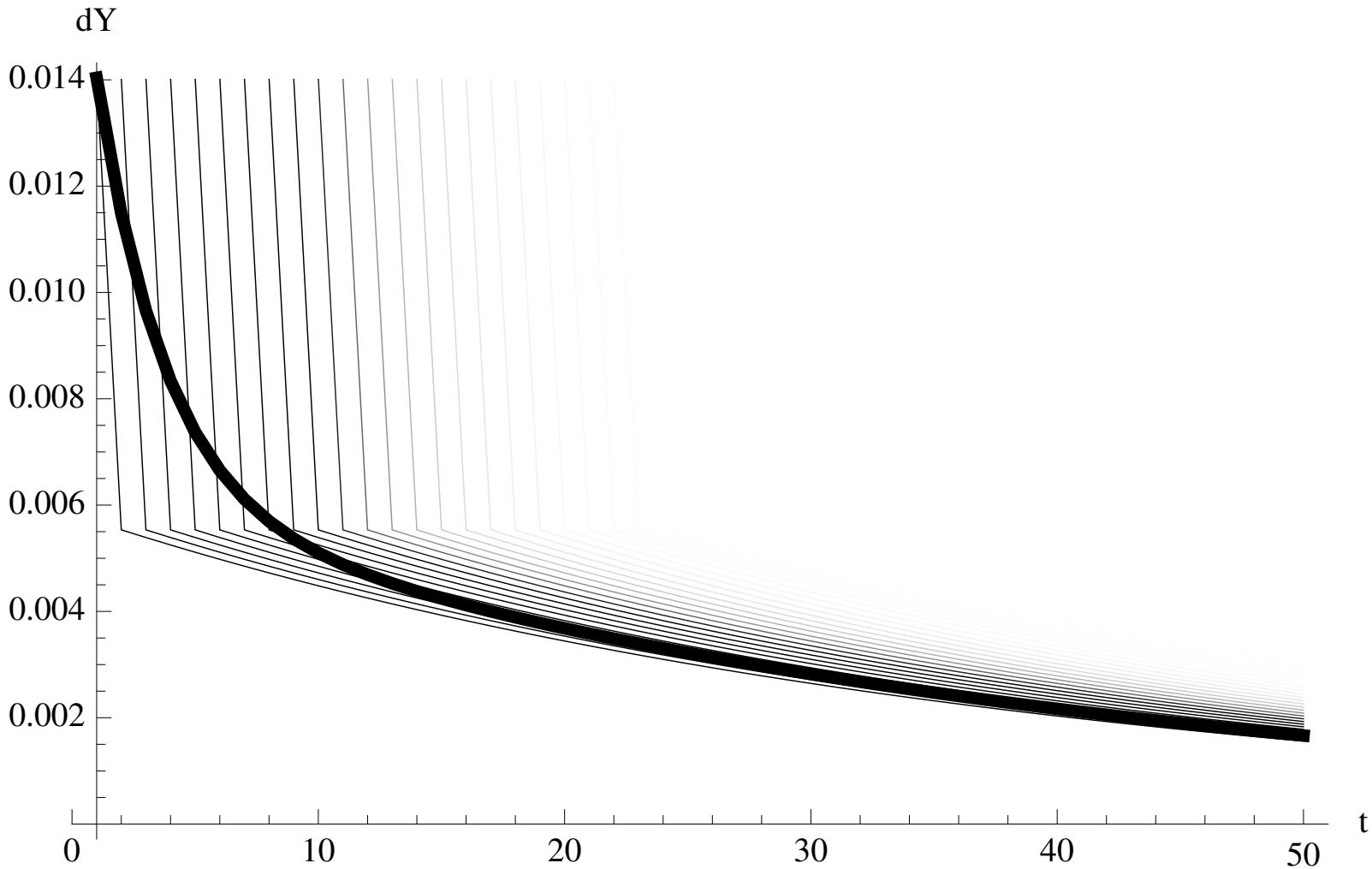


Response of the real interest rate when the duration of debt is 16 quarters

QE Experiment

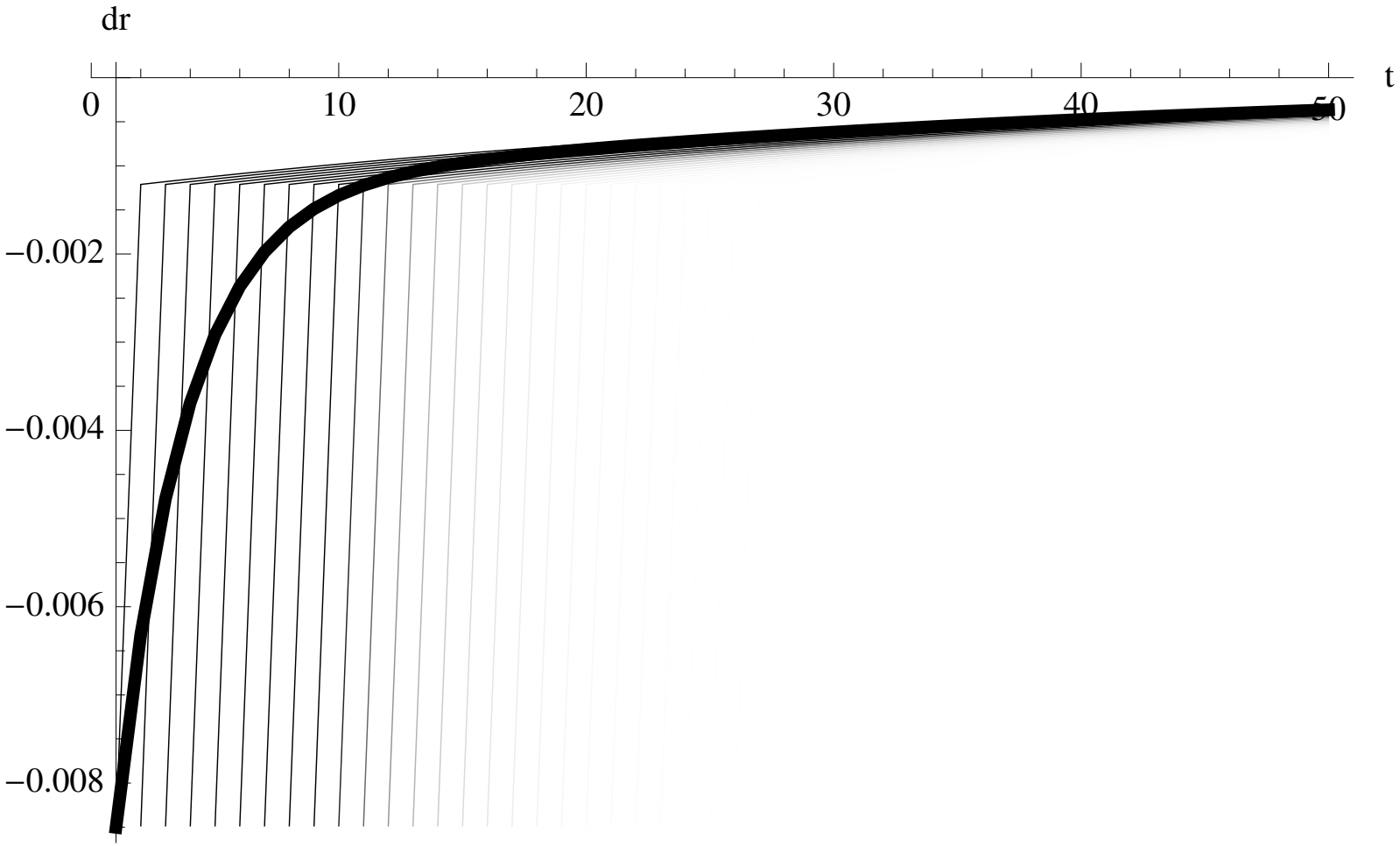
- At the ZLB, keep the level of debt constant
  - Debt 30% above steady-state at ZLB (Dallas-Fed data as of $2008:IV$)
- Reduce the duration of government debt by 7 months, once-and-for-all, starting from 16 qts at the ZLB
  - Based on estimates from Chadha, Turner, and Zampoli (2013) of the effects of the 2011 QE program
  - Results on time-varying duration of government debt later

ZLB-QE-Output



Effects of QE on output

ZLB-QE-Real Interest Rate



Effects of QE on real interest rate

Closing the Output Gap

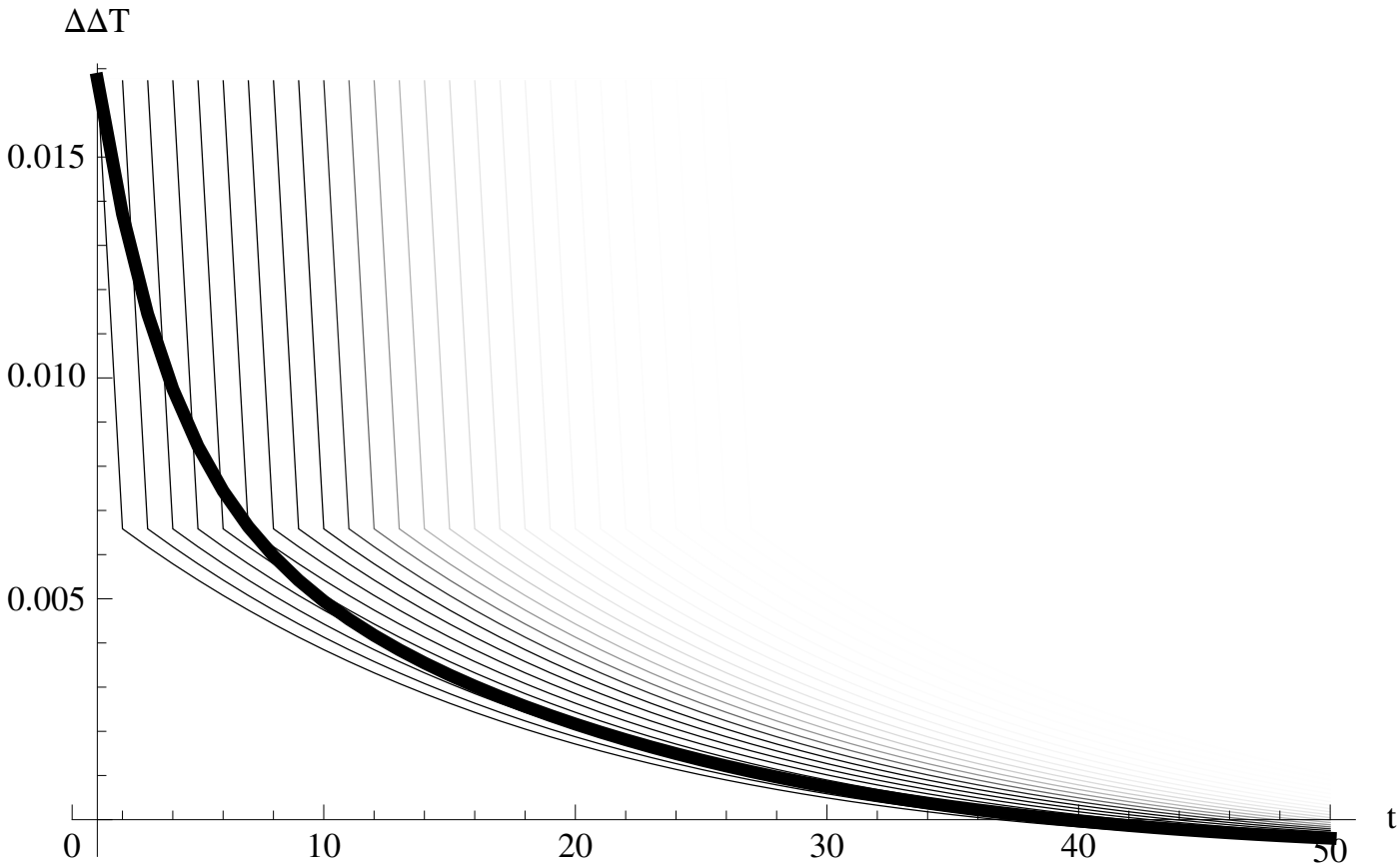
- How big of a reduction in duration of debt completely eliminates the negative output gap at the ZLB?
- Need a policy intervention 3 times the size of our baseline experiment
  - Reduce duration of debt from 16 to 9.11 quarters

Effects of QE on Incentives

- QE provides incentive to keep future short-term real interest rates low
  - The government rolls over more debt at the short-term rate
  - Cost of raising short rates thus higher
- Alternative explanation
  - Show implied changes in taxes from reneging on low interest rates
- Conduct the following experiment
  - Govt deviates from optimal policy out of ZLB and keeps output gap and inflation at zero
  - Does QE make it more costly to renege on optimal policy?

Cost of Reneging on Low Real Rates

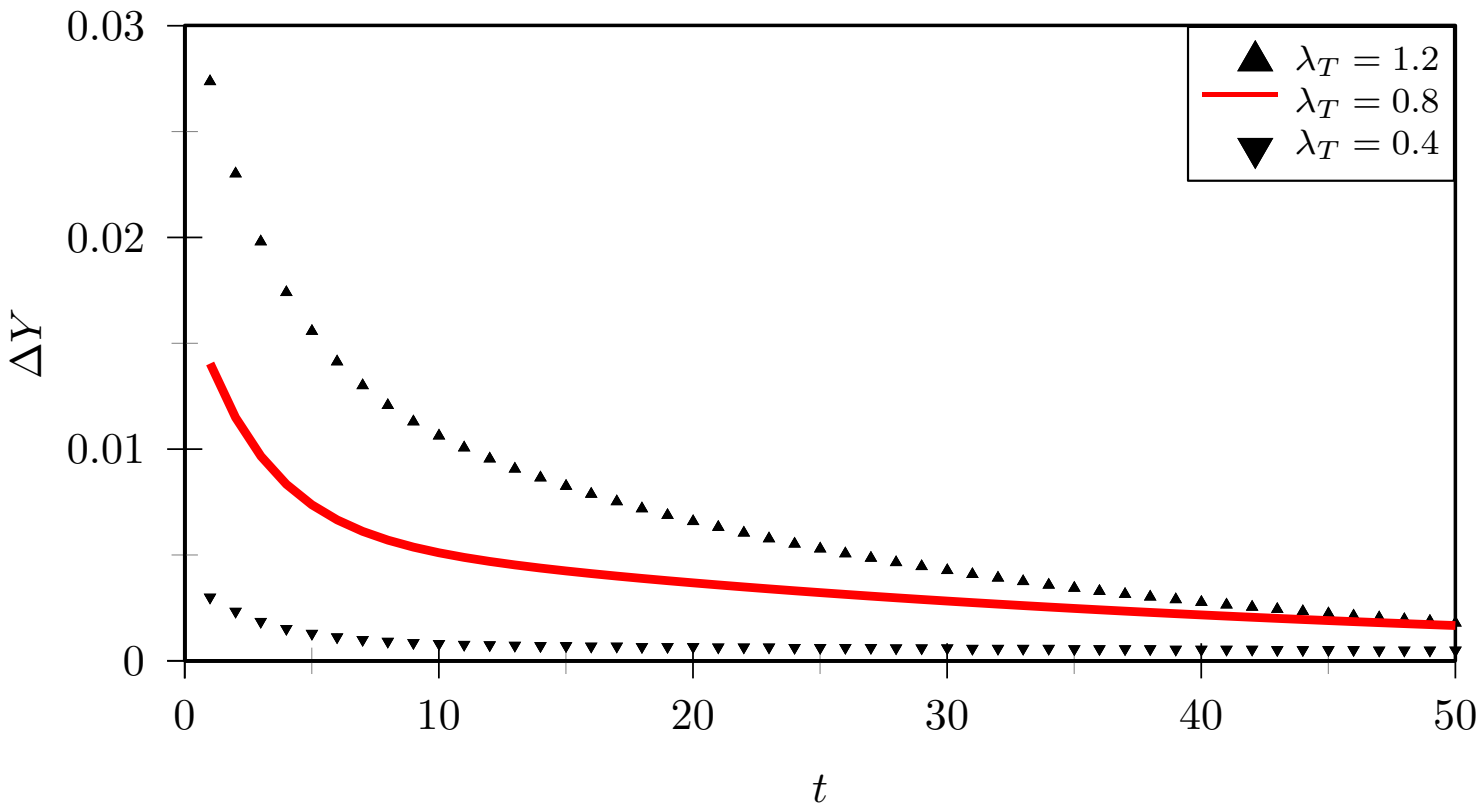
- Greater incentives to keep future real rates low to avoid tax increases



Effects of QE on increase in taxes due to reneging on optimal policy

Robustness

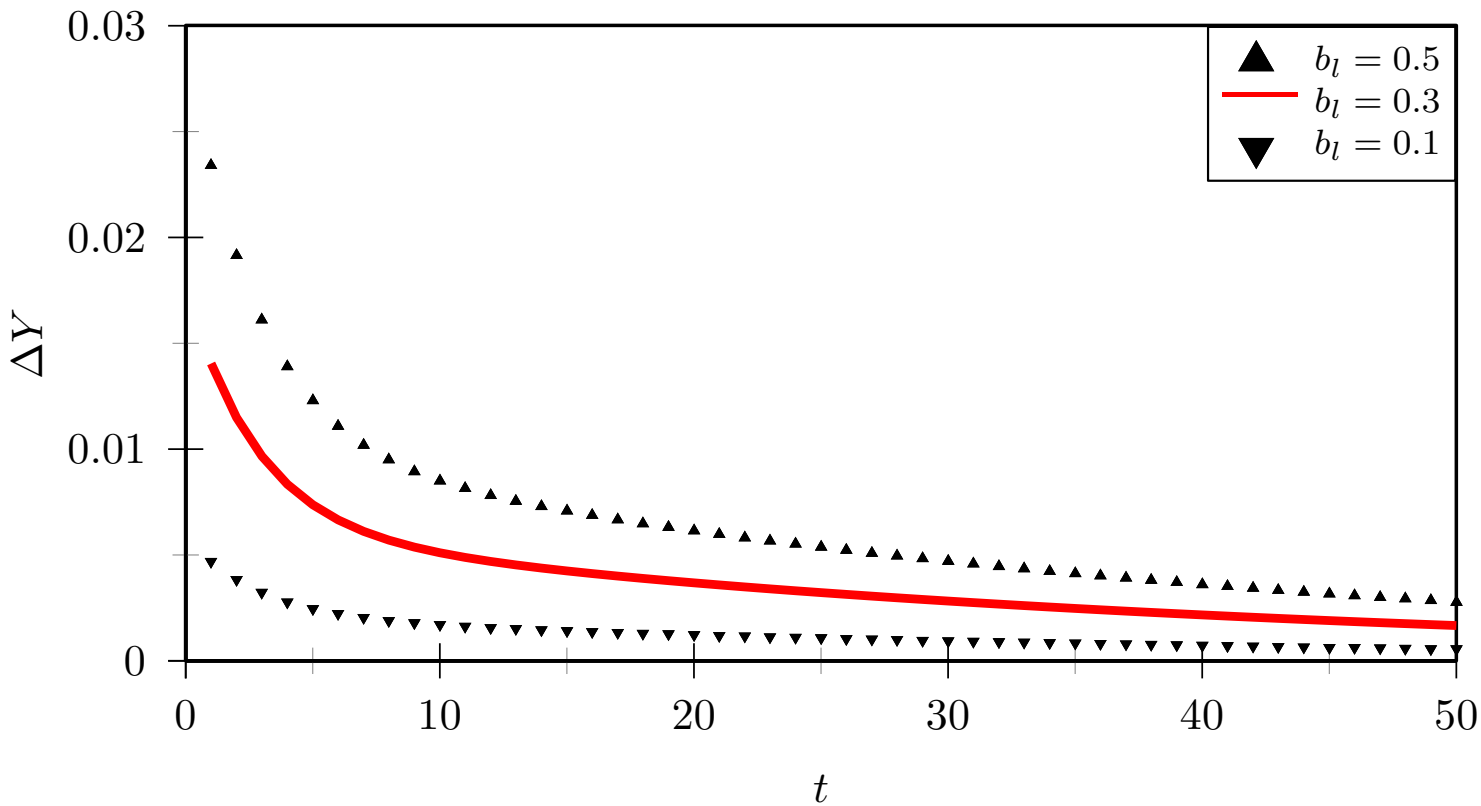
Extent of Tax Distortions



Effects of QE on output at different levels of λ_T

Robustness

Debt at ZLB



Effects of QE on output at different levels of initial debt

Extensions

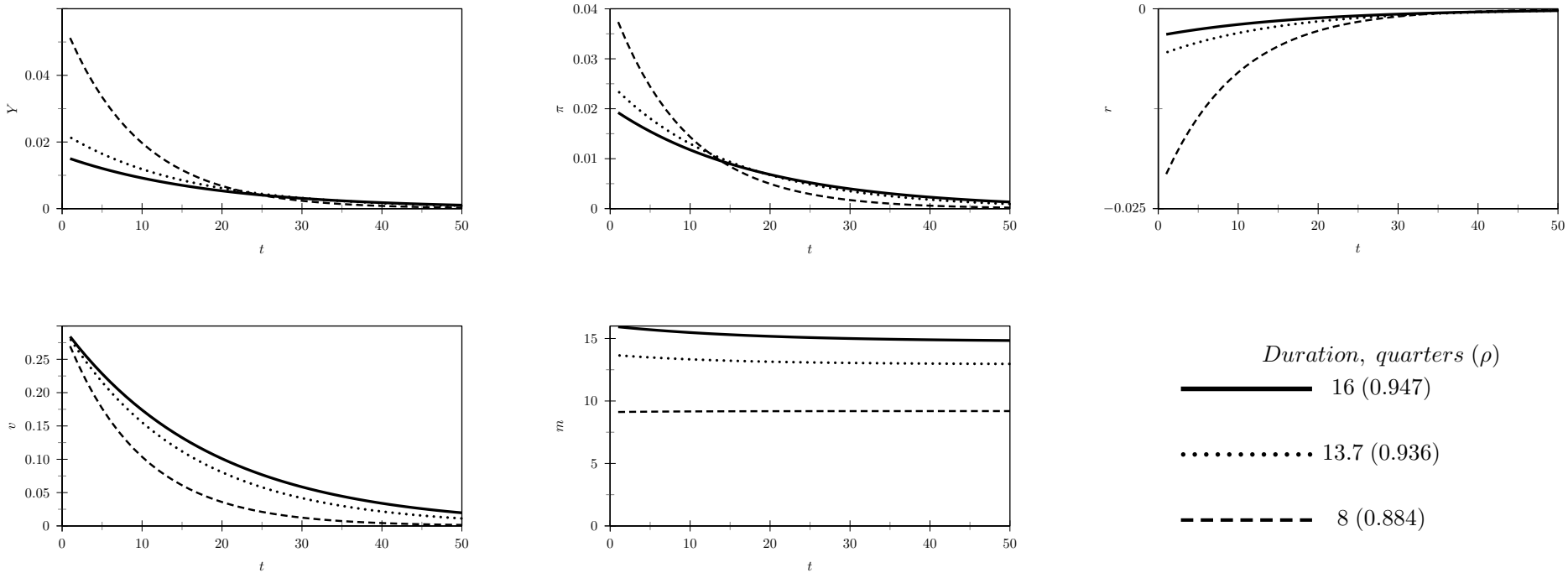
- Time-varying duration
  - Govt optimally chooses the duration of debt after ZLB
  - Need to set-up the full non-linear discretionary problem
- Central Bank balance sheet concerns
  - Political economy justification
  - Central Bank faces a budget constraint and cares directly about transfers to the treasury
- Calibration targeting a fall in nominal interest rates post-QE
  - Baseline calibration leads to a major role for expected inflation (nominal interest rates increase due to QE)
  - Re-calibrate to get both nominal interest rates to fall and expected inflation to rise post-QE while keeping market value of debt constant

Time-varying Duration

- So far, considered a reduction in duration of debt at the ZLB and held it low afterwards
- But, is there an incentive for the govt to increase duration of debt once the economy has recovered?
  - Consider govt choosing the duration of debt optimally after ZLB
- Govt issues a perpetuity bond in period t which pays ρ_t^j dollars $j+1$ periods later
  - Price of a newly issued bond in period t: $S_t(\rho_t)$
  - Price in period t of a bond which pays ρ_{t-1}^j dollars $j+1$ periods later : $W_t(\rho_{t-1})$
- Govt budget constraint
  - $S_t(\rho_t)b_t = \left(1+\rho_{t-1}W_t(\rho_{t-1})\right)b_{t-1}\Pi_t^{-1} + (F - T_t)$

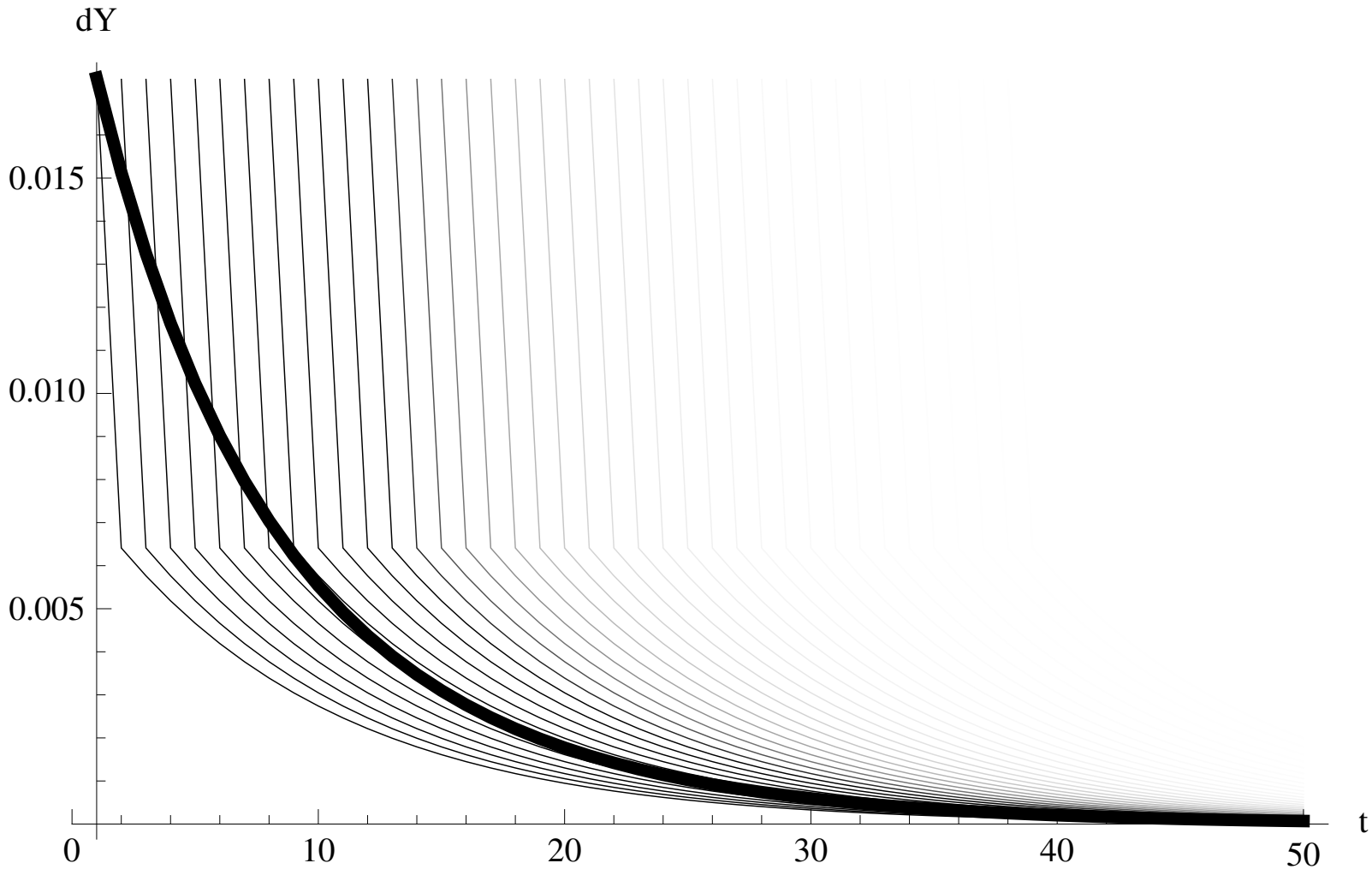
Out of ZLB

IRFs at Different Durations



Responses to a 30% increase in debt outstanding

ZLB-QE-Output



Effects of QE on output

Central Bank Balance Sheet Concerns

- Treasury budget constraint

$$S_t B_t^T = \left(1 + \rho S_t\right) B_{t-1}^T + P_t \left(F_t - T_t - V_t\right)$$

where V_t are transfers from the Central Bank

- Central Bank budget constraint

$$S_t B_t^{CB} + P_t V_t = \left(1 + \rho S_t\right) B_{t-1}^{CB}$$

- Consolidated so far

$$S_t B_t = \left(1 + \rho S_t\right) B_{t-1} + P_t \left(F_t - T_t\right)$$

where $B_t = B_t^T - B_t^{CB}$ is treasury debt held by the public

Central Bank Balance Sheet Concerns

- Now, direct Central Bank balance sheet concerns
  - Treasury makes debt dynamics stable ("passive" fiscal policy)
- Central Bank budget constraint

$$S_t B_t^{CB} + P_t V_t = \left(1 + \rho S_t\right) B_{t-1}^{CB}$$

$$\hat{b}_t^{CB} = \beta^{-1} \hat{b}_{t-1}^{CB} - \beta^{-1} \pi_t - \left(1 - \rho\right) \hat{S}_t - \psi_V \hat{V}_t$$

- Central Bank loss-function

$$-\left[\lambda_\pi \pi_t^2 + \hat{Y}_t^2 + \lambda_V \hat{V}_t^2\right]$$

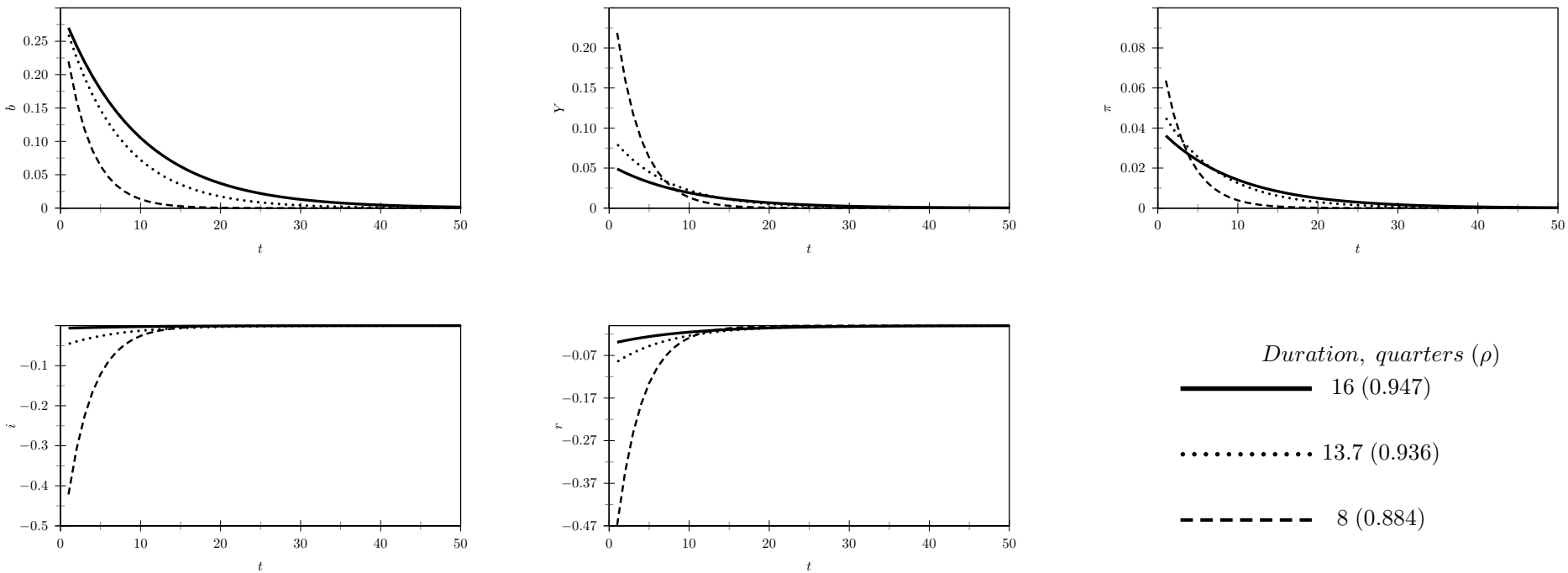
- Experiment is an increase in ρ when $\hat{b}_{t-1}^{CB} < 0$
- Isomorphic to the baseline model

Alternate Calibration

- Current calibration, the real interest rate unambigously falls due to QE
- Nominal interest rates though rise
  - Rise in expected inflation plays the major role
- Change σ to 0.5 (from 1)
- Recalibrate μ and r_L^e such that again at the ZLB
  - Drop in output of 10%
  - Drop in inflation of 2% (annualized)

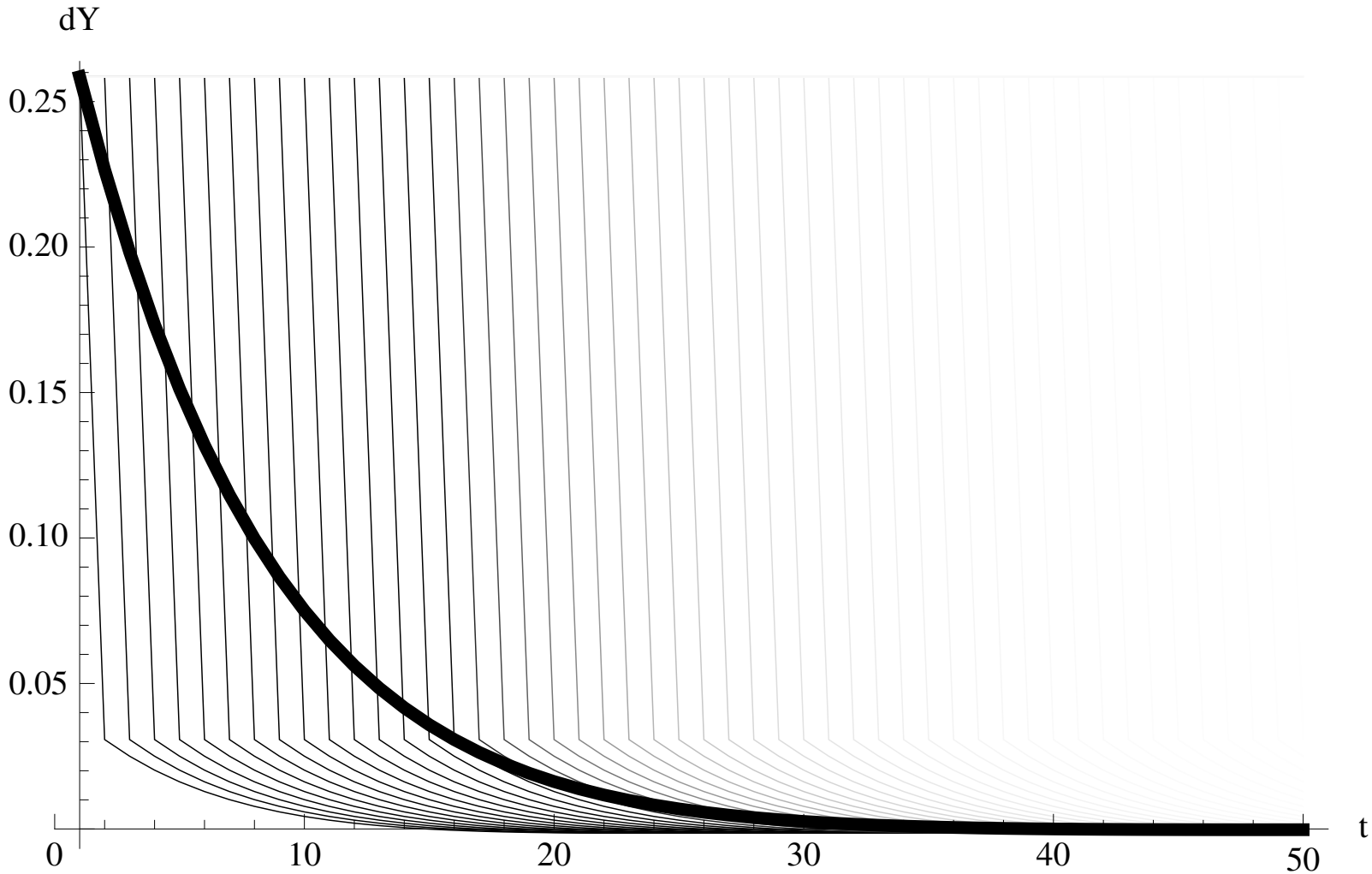
Alternate Calibration - Out of ZLB

IRFs at Different Durations



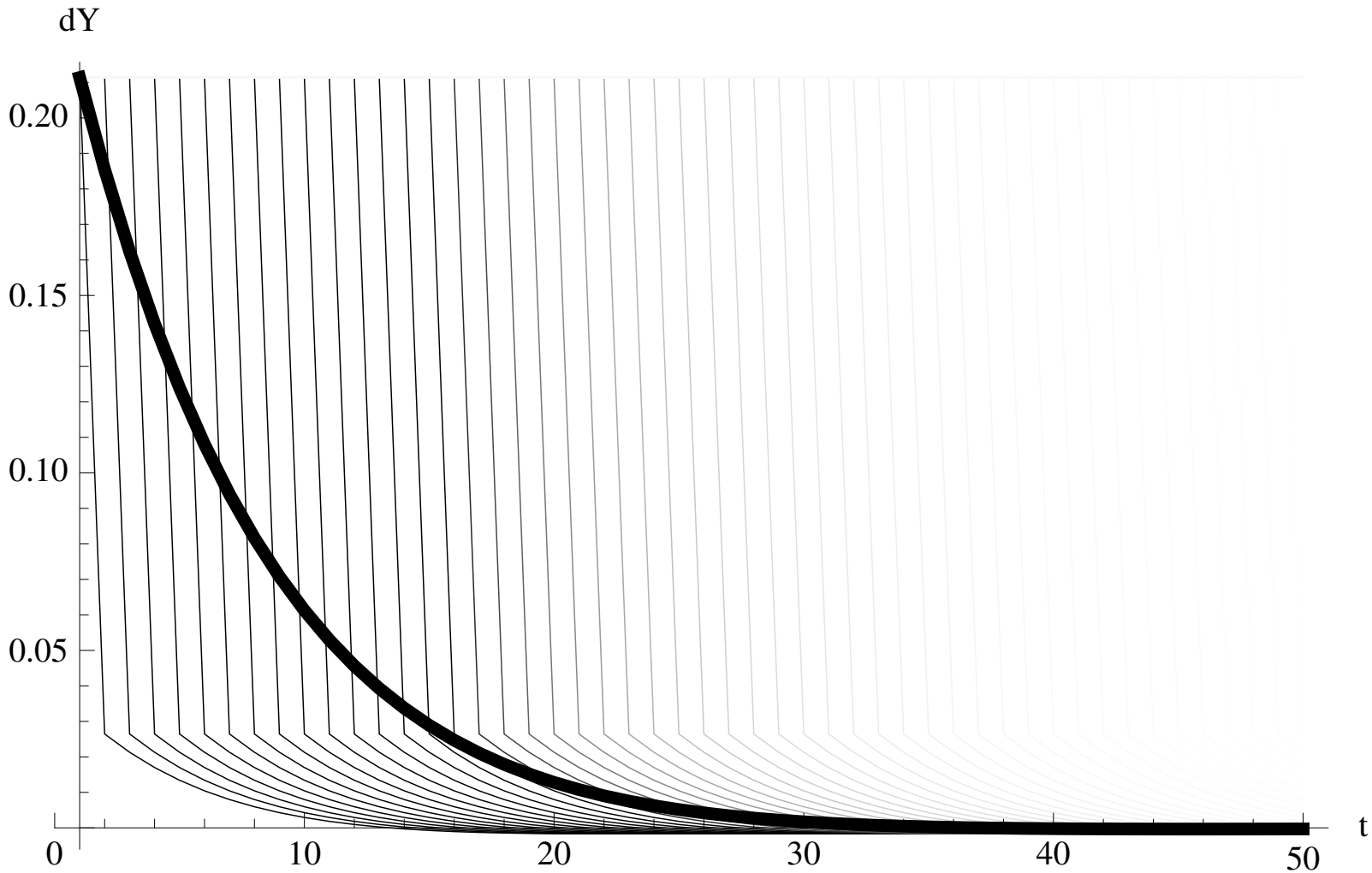
Responses to a 30% increase in debt outstanding

Alternate Calibration-ZLB-QE-Output



Effects of QE on output

Alternate Calibration-ZLB-QE-Output



Effects of QE on output (constant mkt value of debt)

Conclusion

- Provide a model without financial frictions where QE is not neutral
- QE affects expectations about future policy actions and provides a commitment device
  - A "signalling" role
- In a time-consistent equilibrium, shortening the maturity of outstanding government debt provides incentives to keep short-term real interest rates low in future
- In ZLB, QE thus helps avoid negative output gap and deflation
- Reduction of duration by 7 months increases output by 140 bp

Related Literature

- Appropriate manipulation of maturity composition of government debt can help overcome time-inconsistency
  - Flexible price models without ZLB focus
  - Lucas and Stokey (1983), Persson, Persson, and Svensson (1987, 2006), Alvarez, Kehoe, and Neumeyer (2004)
- At ZLB, issuing nominal debt or buying foreign exchange provides a commitment device
  - Eggertsson (2006) and Jeanne and Svensson (2007)
- Recent discussion of whether reduction of long-term rates due to the risk-premium and/or the signalling channel
  - Woodford (2012)
- Central bank purchase of private sector assets
  - Gertler and Karadi (2011) and Gertler and Kiyotaki (2011)

Future Work

- Allow time-variation in debt maturity to have an effect on real variables
  - Will require a second-order approximation
- Full quantitative evaluation of the mechanism
  - DSGE models with more frictions (of the type used in policy evaluation)