The Effectiveness of Alternative Monetary Policy Tools in a Zero Lower Bound Environment

James D. Hamilton Jing (Cynthia) Wu

Department of Economics
UC San Diego

What more can monetary policy do when:

- the fed funds rate is 0.18%
- reserves are over a trillion dollars?

Policy options

1. Communicate expansionary intentions after escape from the zero lower bound

Policy options

1. Communicate expansionary intentions after escape from the zero lower bound
2. Purchase assets other than T-bills
   a. foreign assets
   b. risky assets
   c. long-term assets

Preferred habitat model of Vayanos and Vila

Preferred habitat model of Vayanos and Vila

- preference of some borrowers or lenders for certain maturities
- arbitrageurs ensure that each risk factor is priced the same across assets

Preferred habitat model of Vayanos and Vila

Preferred habitat model of Vayanos and Vila

- preference of some borrowers or lenders for certain maturities
- arbitrageurs ensure that each risk factor is priced the same across assets
- decreased preference of Treasury to borrow long-term
  $\Rightarrow$ reduced exposure of arbitrageurs to long-term risk factors
  $\Rightarrow$ reduced price of this risk (flatter yield curve)

Outline

1. Model

   .

2. Data

   .

3. Empirical results prior to crisis

   .

4. Model and empirical results at the ZLB

Discrete-time version of Vayanos and Vila (2009)

Arbitrageurs' objective:

$$\max E_t(r_{t,t+1}) - (\gamma/2) Var_t(r_{t,t+1})$$

- first-order condition:

$$y_{1t} = E_t(r_{n,t,t+1}) - \gamma \vartheta_{nt}$$

where y_{1t} = return on riskless asset
ϑ_{nt} = (1/2) change in variance from one more unit of asset n

Discrete-time version of Vayanos and Vila (2009)

Arbitrageurs' objective:

$$\max E_t(r_{t,t+1}) - (\gamma/2) Var_t(r_{t,t+1})$$

- first-order condition:

$$y_{1t} = E_t(r_{n,t,t+1}) - \gamma \vartheta_{nt}$$

where y_{1t} = return on riskless asset

ϑ_{nt} = (1/2) change in variance from one more unit of asset n

Rate of return

$$\begin{aligned} r_{n,t,t+1} &= \frac{P_{n-1,t+1}}{P_{nt}} - 1 \\ r_{t,t+1} &= \sum_{n=1}^{N} z_{nt} r_{n,t,t+1} \end{aligned}$$

Discrete-time version of Vayanos and Vila (2009)

Suppose that log of bond price is affine function of macro factors f_t,

$$\log P_{nt} = \bar{a}_n + \bar{b}_n' f_t$$

and factors follow Gaussian VAR(1):

$$f_{t+1} = c + \rho f_t + \Sigma u_{t+1}$$

Discrete-time version of Vayanos and Vila (2009)

Suppose that log of bond price is affine function of macro factors f_t,

$$\log P_{nt} = \bar{a}_n + \bar{b}_n' f_t$$

and factors follow Gaussian VAR(1):

$$f_{t+1} = c + \rho f_t + \Sigma u_{t+1}$$

Then variance of return on portfolio is approximately

$$d_t' \Sigma \Sigma' d_t$$

$$d_t = \sum_{n=2}^{N} z_{nt} \bar{b}_{n-1}$$

and (1/2) derivative of variance with respect to asset n is

$$\vartheta_{nt} = \bar{b}_{n-1}' \Sigma \Sigma' d_t$$

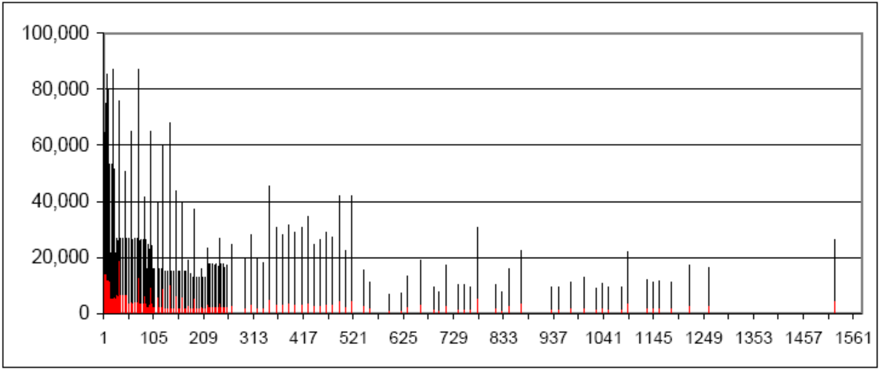
Discrete-time version of Vayanos and Vila (2009)

If preferred-habitat borrowing is also an affine function of f_t, then in equilibrium, prices of risk are an affine function of factors as well, and framework implies a standard affine-term-structure model.

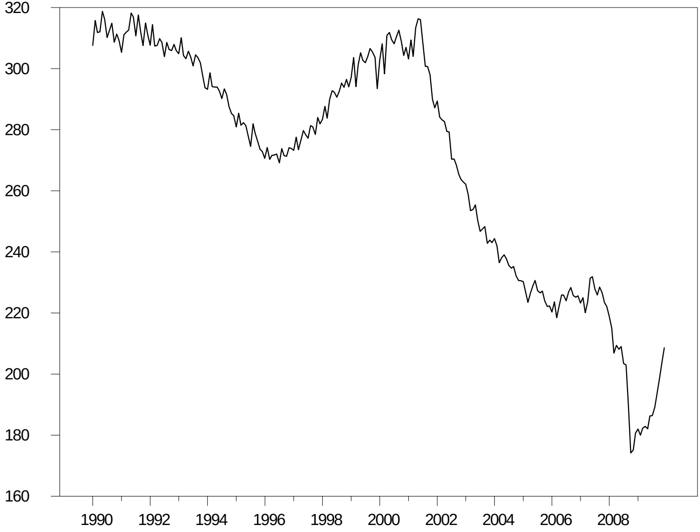
Data

- Treasury yields (weekly and end-of-month, Jan 1990 - Aug 2010)
- Face value of outstanding Treasury debt (1990.M1-2009.M12)
- Separate estimates of Fed holdings

Maturity structure: December 31, 2006



Average maturity



Prior to Crisis

Setup

- 3-factor model, estimated weekly Jan 1990 - July 2007, assuming only that prices of risk are affine in the factors
- Factors f_t: level, slope and curvature

$$\begin{aligned} \text{level} &= \left(y_{6m} + y_{2y} + y_{10y}\right)/3 \\ \text{slope} &= y_{10y} - y_{6m} \\ \text{curvature} &= y_{6m} + y_{10y} - 2y_{2y} \end{aligned}$$

- Yields measured with error: 3m, 1y, 5y and 30y
- generates estimates of factor dynamic parameters (c, ρ, Σ), risk-pricing parameters (λ, Λ), and how each maturity loads on factors $\bar{b}_n$.

Results

c	-0.0034 (0.0089)	-0.0003 (0.0074)	0.0006 (0.0066)	
ρ	0.9895 (0.0072)	0.0042 (0.0081)	-0.0244 (0.0157)	
	0.0083 (0.0047)	0.9826 (0.0081)	0.0478 (0.0123)	
	-0.0013 (0.0041)	0.0055 (0.0058)	0.9755 (0.0132)	
$a_1 \times 5200$	4.1158 (0.0074)			
$b_1 \times 5200$	1.0345 (0.0058)	-0.6830 (0.0081)	0.6311 (0.0189)	
Σ	0.1094 (0.0236)	0	0	
	0.0360 (0.0100)	0.1027 (0.0045)	0	
	-0.0670 (0.0188)	0.0025 (0.0130)	0.0968 (0.0149)	
$\Sigma_e \times 5200$	0.0978 (0.0023)	0	0	0
	0	0.0674 (0.0016)	0	0
	0	0	0.0531 (0.0013)	0
	0	0	0	0.1171 (0.0028)

λ	-0.1378 (0.0717)	0.1604 (0.0727)	-0.0564 (0.0687)
Λ	-0.0867 (0.0468)	-0.0480 (0.0594)	-0.0948 (0.1203)
	0.0847 (0.0455)	-0.0266 (0.0825)	0.1773 (0.1200)
	-0.0567 (0.0436)	0.0531 (0.0596)	-0.1862 (0.1594)

Preferred habitat

Preferred-habitat-implied price of risk

$$\Sigma\lambda_t = \gamma\Sigma\Sigma' \sum_{n=2}^{N} z_{nt}\bar{b}_{n-1}$$

Preferred habitat

Preferred-habitat-implied price of risk

$$\Sigma\lambda_t = \gamma\Sigma\Sigma' \sum_{n=2}^{N} z_{nt}\bar{b}_{n-1}$$

Suppose that:

- arbitrageurs correspond to entire private sector
- U.S. Treasury debt is sole asset held by arbitrageurs

Preferred habitat

Preferred-habitat-implied price of risk

$$\Sigma\lambda_t = \gamma\Sigma\Sigma' \sum_{n=2}^{N} z_{nt}\bar{b}_{n-1}$$

Suppose that:

- arbitrageurs correspond to entire private sector
- U.S. Treasury debt is sole asset held by arbitrageurs

Then:

z_{nt} = share of publicly-held debt represented by maturity n

Preferred habitat

Preferred-habitat-implied price of risk

$$\Sigma\lambda_t = \gamma\Sigma\Sigma' \sum_{n=2}^{N} z_{nt}\overline{b}_{n-1}$$

Suppose that:

- arbitrageurs correspond to entire private sector
- U.S. Treasury debt is sole asset held by arbitrageurs

Then:

z_{nt} = share of publicly-held debt represented by maturity n

$$q_t = 100\Sigma\Sigma' \sum_{n=2}^{N} z_{nt}\overline{b}_{n-1}$$

Excess holding returns

- Excess holding return
  e.g. hold 5 year bond over 1 year

$$h_{5,1,t} = \log \frac{P_{4,t+1}}{P_{5,t}} - y_{1,t}$$

Excess holding returns

- Excess holding return
  e.g. hold 5 year bond over 1 year

$$h_{5,1,t} = \log \frac{P_{4,t+1}}{P_{5,t}} - y_{1,t}$$

- Regression

$$h_{nkt} = c_{nk} + \beta'_{nk} f_t + \gamma'_{nk} x_t + u_{nkt}.$$

Excess holding returns

- Excess holding return
  e.g. hold 5 year bond over 1 year

$$h_{5,1,t} = \log \frac{P_{4,t+1}}{P_{5,t}} - y_{1,t}$$

- Regression

$$h_{nkt} = c_{nk} + \beta'_{nk} f_t + \gamma'_{nk} x_t + u_{nkt}.$$

.

- Expectation hypothesis: excess holding returns are unpredictable
- ATSM: f_t contains all the information at t

Regressors	6m over 3m	1yr over 6m	2y over 1y	5y over 1y	10y over 1y
f_t^*	**0.357**	**0.356**	**0.331**	**0.295**	**0.331**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
f_t, z_t^{A*}	**0.410**	0.420	0.373	0.300	0.336
	(0.020)	(0.119)	(0.311)	(0.728)	(0.665)
f_t, z_t^{L*}	**0.428**	**0.501**	**0.524**	**0.398**	0.357
	(0.003)	(0.008)	(0.006)	(0.035)	(0.196)
f_t, q_t^*	**0.444**	**0.568**	**0.714**	**0.617**	**0.549**
	(0.002)	(0.000)	(0.000)	(0.000)	(0.001)
f_t, z_t^A, z_t^L, q_t^*	**0.476**	**0.597**	**0.741**	**0.670**	0.634
	(0.000)	(0.001)	(0.000)	(0.002)	(0.054)

.

f_t: term structure factors

z_t^A: average maturity

z_t^L: fraction of outstanding debt over 10 years

q_t: Treasury factors

Endogeneity

Goal: if maturities of outstanding debt change, how would yields change?

Endogeneity

Goal: if maturities of outstanding debt change, how would yields change?

Conventional regression

$$f_t = c + \beta q_t + \varepsilon_t$$

Endogeneity

Goal: if maturities of outstanding debt change, how would yields change?

Conventional regression

$$f_t = c + \beta q_t + \varepsilon_t$$

Concerns:

- Is f_t responding to q_t, or is q_t responding to f_t?

Endogeneity

Goal: if maturities of outstanding debt change, how would yields change?

Conventional regression

$$f_t = c + \beta q_t + \varepsilon_t$$

Concerns:

- Is f_t responding to q_t, or is q_t responding to f_t?
- Spurious regression

Yield factor forecasting regressions

Our approach:

$$f_{t+1} = c + \rho f_t + \phi q_t + \varepsilon_{t+1}$$

Yield factor forecasting regressions

Our approach:

$$f_{t+1} = c + \rho f_t + \phi q_t + \varepsilon_{t+1}$$

Advantages:

- answers forecasting question of independent interest

Yield factor forecasting regressions

Our approach:

$$f_{t+1} = c + \rho f_t + \phi q_t + \varepsilon_{t+1}$$

Advantages:

- answers forecasting question of independent interest
- avoids spurious regression problem

Yield factor forecasting regressions

Our approach:

$$f_{t+1} = c + \rho f_t + \phi q_t + \varepsilon_{t+1}$$

Advantages:

- answers forecasting question of independent interest
- avoids spurious regression problem
- nonzero ϕ does not reflect response of q_t to f_t

Yield factor forecasting regressions

Our approach:

$$f_{t+1} = c + \rho f_t + \phi q_t + \varepsilon_{t+1}$$

Advantages:

- answers forecasting question of independent interest
- avoids spurious regression problem
- nonzero ϕ does not reflect response of q_t to f_t
- estimate incremental forecasting contribution of q_t beyond that in f_t

Significance of Treasury factors

F test that $\phi = 0$

$$f_{t+1} = c + \rho f_t + \phi q_t + \varepsilon_{t+1}$$

	F test
level	**3.256**
	(0.023)
slope	**4.415**
	(0.005)
curvature	**2.672**
	(0.049)

Quantitative illustration

- Fed sells all Treasury securities <1 year, and uses proceeds to buy up long-term debt
- E.g. in Dec. 2006, the effect would be to sell \$400B short-term securities and buy all bonds >10 year

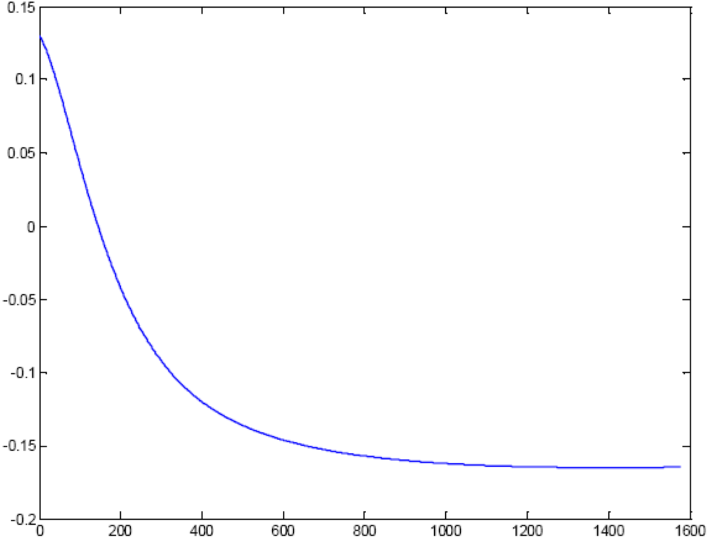
Quantitative illustration

- Fed sells all Treasury securities $<$ 1 year, and uses proceeds to buy up long-term debt
- E.g. in Dec. 2006, the effect would be to sell \$400B short-term securities and buy all bonds $>$ 10 year

	$\phi_i'\Delta$
level	0.005
	(0.112)
slope	$-$**0.250**
	(0.116)
curvature	$-$0.073
	(0.116)

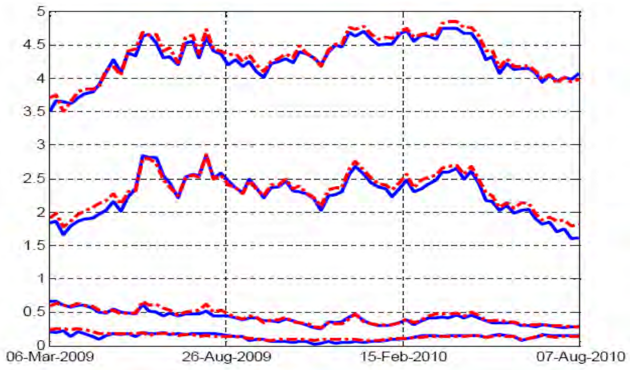
- Δ: average change in q_t

Impact on yield curve 1-month ahead



Financial Crisis and Zero Lower Bound

Zero Lower Bond



- Short term yields near zero
- Longer term yields considerable fluctuation.
- Explanation: when escape from ZLB (with a probability), interest rates will respond to f_t as before

Parsimonious Model of ZLB

- Same underlying factors f_t

$$f_{t+1} = c + \rho f_t + \Sigma u_{t+1}$$

same (c, ρ, Σ)

Parsimonious Model of ZLB

- Same underlying factors f_t

$$f_{t+1} = c + \rho f_t + \Sigma u_{t+1}$$

same (c, ρ, Σ)

- Once escape from ZLB

$$\tilde{y}_{1t} = a_1 + b_1' f_t$$

$$\tilde{p}_{nt} = \bar{a}_n + \bar{b}_n' f_t$$

$\bar{a}_n$ and $\bar{b}_n$ calculated from the same difference equations

Parsimonious Model of ZLB

- At ZLB

$$y_{1t}^* = a_1^*$$

$$p_{nt}^* = \bar{a}_n^* + \bar{b}_n^{*\prime} f_t.$$

π^Q: probability still at ZLB next period
No-arbitrage:
Can calculate $\bar{b}_n^*$ (how bond prices load on factors at ZLB) as functions of $\bar{b}_n$ (how they'd load away from the ZLB) along with π^Q (probability of remaining at ZLB), ρ (factor dynamics), and Λ (risk parameters).

Parsimonious Model of ZLB

Assume: $(c^Q, \rho^Q, a_1, b_1, \Sigma)$ as estimated pre-crisis
$\Rightarrow (\bar{a}_n, \bar{b}_n)$ same as before
Estimate two new parameters $\left(a_1^*, \pi^Q\right)$ to describe 2009:M3-2010:M7 data from

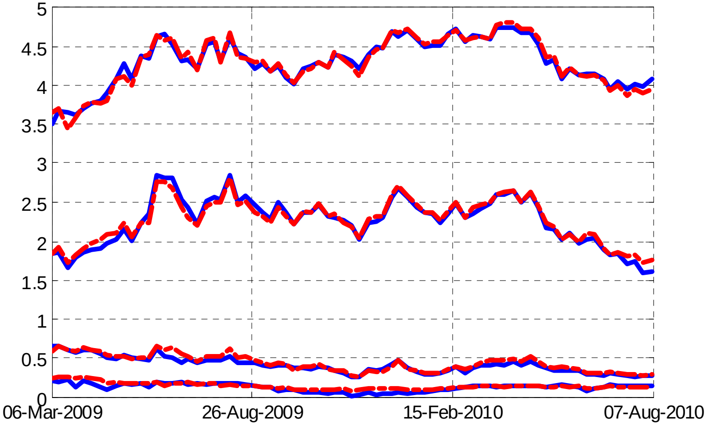
$$Y_{2t} = A_2^{\dagger} + B_2^{\dagger} Y_{1t} + \varepsilon_t^e$$

- Y_{1t} = 6-month, 2-year, 10-year
- Y_{2t} = 3-month, 1-year, 5-year, 30-year
- $A_2^{\dagger}, B_2^{\dagger}$ functions of $(c^Q, \rho^Q, a_1, b_1, \Sigma)$ and $\left(a_1^*, \pi^Q\right)$
- Estimation method: minimum chi square (Hamilton and Wu, 2010)

Parameter estimates for ZLB

Slightly better fit if allow new value for a_1 after escape from ZLB
$5200a_1^* = 0.068$ (ZLB $= 0.07\%$ interest rate)
$\pi^Q = 0.9907$ (ZLB may last 108 weeks)
$5200a_1 = 2.19$ (compares with $5200a_1 = 4.12$ pre-crisis–
market expects lower post-ZLB rates than seen pre-crisis)

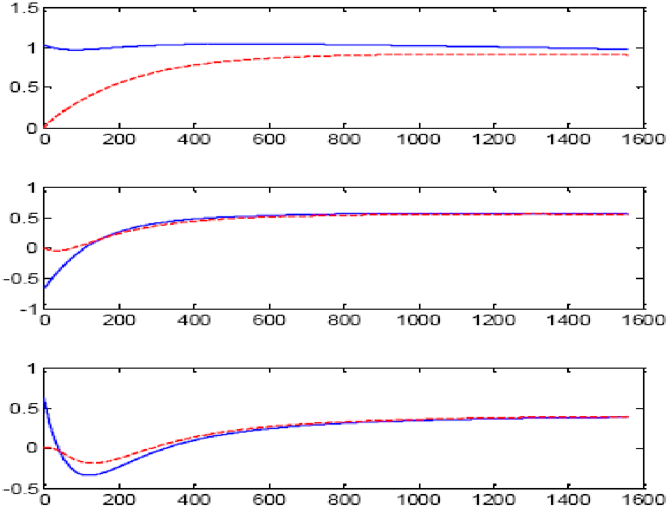
Actual and fitted values



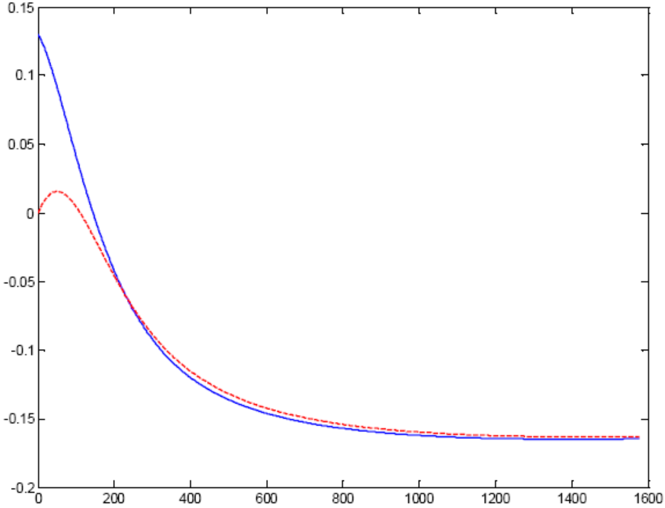
Model Fit

	Contemporaneous R^2		Forecast R^2	
	restricted	unrestricted	restricted	unrestricted
3m	0.625	0.668	0.522	0.602
1y	0.891	0.924	0.652	0.767
5y	0.961	0.975	0.753	0.753
30y	0.965	0.972	0.735	0.787

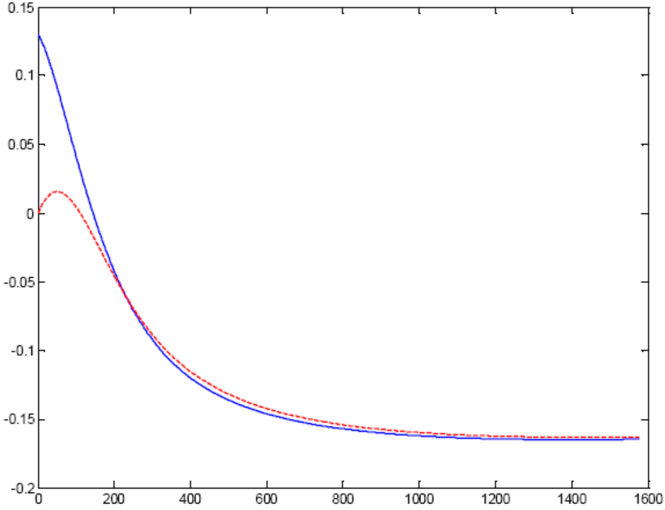
Factor Loadings



One-month-ahead predicted effect of Fed swapping short-for long-term



One-month-ahead predicted effect of Fed swapping short-for long-term



		Original estimates		Hamilton-Wu estimates	
Study	Measure	Pre-crisis	ZLB	Pre-crisis	ZLB
Gagnon, et. al.	10 yr yield	20		14	13
Greenwood-Vayanos	5yr-1yr spread	39		17	9
	20yr-1yr spread	74		25	18
D'Amico-King	10yr yield		67	14	13
Deutsche Bank	10yr yield		20	14	13

Table 5: Comparison of different estimates of the effect of replacing $400 billion in long-term debt with short-term debt.

Caveats

Caveats

- The effects come in the model from investors' assumption that the changes are permanent

Caveats

Caveats

- The effects come in the model from investors' assumption that the changes are permanent
- The Treasury is better suited to implement than Fed

Caveats

Caveats

- The effects come in the model from investors' assumption that the changes are permanent
- The Treasury is better suited to implement than Fed
- Operation works by transferring risk from government's creditors to the Treasury-Fed