# Monetary Policy, Segmentation, and the Term Structure

Rohan Kekre
Chicago Booth

Moritz Lenel
Princeton

Federico Mainardi
Chicago Booth

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# Monetary policy and the term structure

- Effect of change in short rates on (real) long rates is central to monetary transmission.
- Transmission operates in part through term premia.
    - Long rate $= \sum E$[short rates] $+$ term premium.
    - Expansionary MP $\Rightarrow$ long rates fall more than $\sum E$[short rates].

      Cochrane-Piazzesi (02), Gertler-Karadi (15), Hanson-Stein (15), Abrahams-Adrian-Crump-Moench-Yu (16), Hanson-Lucca-Wright (21), ...
- Challenge to rationalize using existing models.
    - Rep. agent: MP shocks have negligible effects on term premia.
    - Preferred habitat: MP easing *raises* term premia.

# What we do

Propose a model of term structure consistent with effects of MP.

- As in preferred habitat tradition: habitat investors + arbs.
- As in intermediary AP tradition: arb wealth is state variable.
- Key mechanism: when arbs have positive duration, fall in short rate revalues wealth in arbs' favor and compresses term premia.

⇒ Accounts for effects of MP shock on real term structure.

⇒ State-dependence, price volatility, and trends from declining $r^*$.

# Outline

▸ Related literature

# Model (1/2)

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- Two types of agents:
  - Habitat investors: $Z_t^{(\tau)} = -\alpha(\tau) \log \left( P_t^{(\tau)} \right) - \theta_t(\tau)$.
  - Arbitrageurs born and dying at rate $\xi$, solving:

$$v_t(w_t) = \max_{\{x_{t+s}^{(\tau)}\}_{\tau,s}} \mathbb{E}_t \int_0^{\infty} \exp(-\xi s) \log w_{t+s} ds$$

subject to

$$dw_t = r_t w_t dt + \int_0^{\infty} x_t^{(\tau)} \left( \frac{dP_t^{(\tau)}}{P_t^{(\tau)}} - r_t dt \right) d\tau.$$

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Optimal policies linear in $w_t$. Define $X_t^{(\tau)}$, $W_t$ as aggregates.

# Model (2/2)

- Market clearing: $Z_t^{(\tau)} + X_t^{(\tau)} = 0$ at each $\tau \in (0, \infty)$.
- Driving forces:
  - Short rate: $dr_t = \kappa_r (\bar{r} - r_t)\, dt + \sigma_r dB_{r,t}$.
  - Habitat demand: $d\beta_t = -\kappa_\beta \beta_t dt + \sigma_\beta dB_{\beta,t}$, where

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- Remarks:
  - Vayanos-Vila (21) + CRRA + perpetual youth.
  - Real interpretation.
  - Monetary shocks as inducing real short rate shocks.

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- Focus on effects of monetary shock $d\epsilon_{r,t}$.

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**Proposition**

*In response to a monetary shock*

$$d \log W_t = -\exp(-\xi)\omega\sigma_r d\epsilon_{r,t},$$

*where $\omega$ is the duration of arbitrageurs' wealth and satisfies $\omega \propto \frac{X}{W}$.*

- Hence, arbs' wealth is revalued upwards if short rate falls and their portfolio has positive duration.

# Effect on yield curve

**Proposition**

*The response of the one-period ahead forward rate to a monetary shock is*

$$df_t = \left[\frac{1 - \kappa_r - \frac{1}{W}\alpha\sigma_r^2}{1 + \frac{1}{W}\alpha\sigma_r^2}\right]\sigma_r d\epsilon_{r,t},$$

- Yield falls as short rate falls and habitat investors borrow more.
- When $\xi \to \infty$, arbs' wealth is constant at $\bar{W}$.
    - Underreaction: $df_t < (1 - \kappa_r)\sigma_r d\epsilon_{r,t} = dE_t r_{t+1}$ if $\alpha > 0$.

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  - Underreaction: $df_t < (1 - \kappa_r)\sigma_r d\epsilon_{r,t} = dE_t r_{t+1}$ if $\alpha > 0$.
- When $\xi$ finite, arbs' wealth revalued upwards.
  - Overreaction: term premium falls if $X/W$ sufficiently high vs. $\alpha$.

# Taking stock and rest of paper

- When $\xi \to \infty$, forward rate underreacts to monetary shock.
- Given finite $\xi$, forward rate overreacts to monetary shock if portfolio duration is high relative to $\alpha$.

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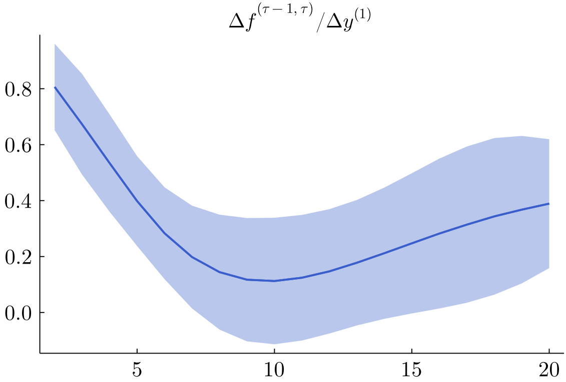
- Given finite $\xi$, forward rate overreacts to monetary shock if portfolio duration is high relative to $\alpha$.
- Now:
  1. Estimates of monetary shock on yield curve.
  2. Estimates of arb duration.
  3. Assessing whether full model can quantitatively account for #1.
     - Arb duration disciplined by novel evidence in #2.
     - $\alpha$ disciplined by large literature on QE.
  4. Additional implications of endogenous arb wealth for yield curve.

# Estimated effects on real yield curve

▸ Details ▸ Scatterplot ▸ Nominal

- $\Delta f_t^{(\tau-1,\tau)}$ on $\Delta y_t^{(1)}$, using high-freq. MP surprise as IV.



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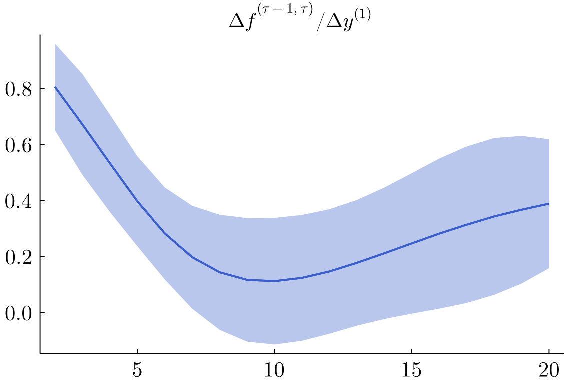


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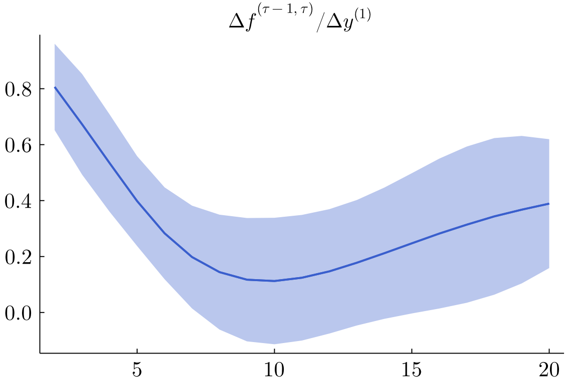


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- Challenge to explain with existing models.

# Estimated arb duration

- Who are the arbs?
  - Following literature, broker/dealers and hedge funds.
  - By market clearing, habitat: households, other fin. institutions (pension funds, life insurance), non-financials, govt, and ROW.
- Two approaches to measure dealer + hedge fund duration:
  1. Balance sheets and asset-specific duration. Details
  2. High-freq. response of dealers to MP surprises. Details
- Punchline: duration between 5 and 20.

# Relating yield curve responses and arb duration

Robustness

- Add MP surprise $\times dur_{t-1}$ to high freq. regressions.
- Use 3 proxies for arb duration avail. over sample: Figures

| | Proxy for arb duration | | |
|---|---|---|---|
| | 5-yr fwd, 5-yr TP | Log dealer dur. | −Dealer income gap |
| $\Delta f_t^{(19,20)}$ on $\Delta y_t^{(1)} \times dur_{t-1}$ | 0.50 | 0.65 | 2.0 |
| | (0.25) | (0.27) | (1.7) |

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- Add'l evidence: High freq. dealer return as RHS in first stage
High freq. dealer return amplified when duration high

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and evolution of driving forces.

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- Assume: $\alpha(\tau) \equiv \alpha \exp^{-\delta\tau}$, $\theta_0(\tau) \equiv \exp^{-\delta\tau}$, $\theta_1(\tau) \equiv \exp^{-\delta\tau}$.

# Calibration: key parameters and targets

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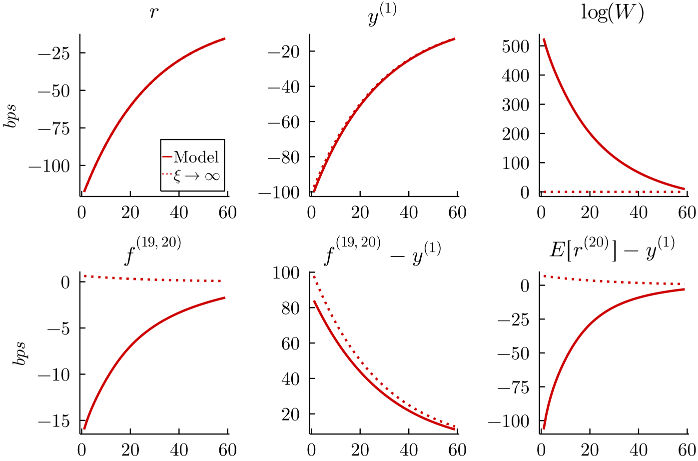
- $\alpha$ (habitat price elast.): responses to QE.
  - Simplified environment provides intuition: $\frac{d \log P_t}{d\theta_t} = -\frac{1}{\alpha + \frac{W_t}{\sigma_r^2}}$.
  - Focus on 3/18/09 announcement: purchase \$300bn Treasuries; increase agency debt and MBS purchases by \$100bn, \$750bn.
  - Translate each security-level purchase through 3/31/10 into purchase of ZCBs and feed into model.
  - Initialize $W_0$ at 40% below average $W$, consistent with data.

Purchases in data | Price impact in data | Arb wealth Q407–Q109 | Simulating QE in model

# Monetary shock: impulse responses

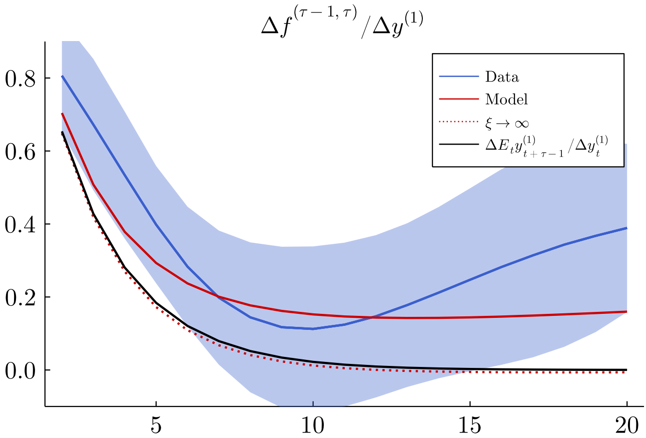
β shock




- Arbs' wealth rises and lowers term premia, unlike $\xi \to \infty$.

# Monetary shock: model vs. data

More persistent shock | CP (08) decomp.

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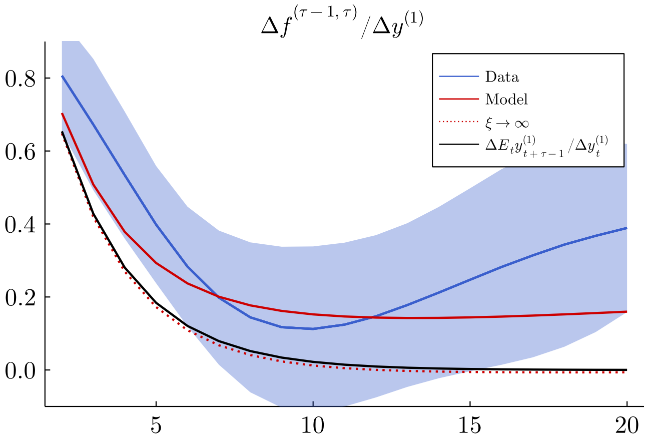


- Account for roughly half of $f^{(19,20)}$, unlike $\xi \to \infty$...
- ...and all of $f^{(19,20)}$ given higher duration/lower $\alpha$. Details

# Monetary shock: state-dependence

| | Proxy for arb duration | | |
|---|---|---|---|
| | 5-yr fwd, 5-yr TP | Log dealer dur. | −Dealer income gap |
| Data | [0.09,0.91] | [0.21,1.09] | [0.6,5.2] |
| Model | 0.14 | 0.12 | 0.3 |

- As in data, higher arb duration implies larger response of $f^{(19,20)}$ to monetary tightening.
- If anything, model understates effects of changes in arb wealth.

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1. State-dependent effects of QE. ▸ Details
   - If arb wealth was $W$ before 3/18/09 announcement, response of long-dated yields and forwards dampened by $20 - 30\%$.
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   - ... generates stochastic vol. in bond prices.
3. Secular decline in natural rate. Details
   - Decline in $\bar{r}$ accounts for $> 20\%$ of decline in real term premia.
   - Complements explanations focused on changing comovements.

# Conclusion

Propose a model of term structure consistent with effects of MP.

- As in preferred habitat tradition: habitat investors + arbs.
- As in intermediary AP tradition: arb wealth is state variable.
- Key mechanism: when arbs have positive duration, fall in short rate revalues wealth in arbs' favor and compresses term premia.

⇒ Accounts for effects of MP shock on real term structure.

⇒ State-dependence, price volatility, and trends from declining $r^*$.

# APPENDIX

# Related literature

Back

- Preferred habitat models of term structure.

  Vayanos-Vila (21), Greenwood-Hanson-Stein (10), Guibaud-Nosbusch-Vayanos (13), Gourinchas-Ray-Vayanos (21), Greenwood-Hanson-Stein-Sunderam (20), Ray (21), ...

  **Here:** resolve counterfactual responses to short rate.

- Intermediary asset pricing and financial accelerator.

  Bernanke-Gertler-Gilchrist (99), He-Krishnamurthy (13), Brunnermeier-Sannikov (14), Haddad-Sraer (20), He-Nagel-Song (22), Schneider (22), ...

  **Here:** application to term structure and monetary transmission.

- "Reaching for yield" or changing policy rules.

  Hanson-Stein (15), Bianchi-Lettau-Ludvisgon (21), Hanson-Lucca-Wright (21), Bianchi-Ludvigson-Ma (22), Bauer-Pflueger-Sunderam (22), ...

  **Here:** wealth revaluation channel with distinct predictions.

- Our prior work on macro, wealth distribution, and price of risk.

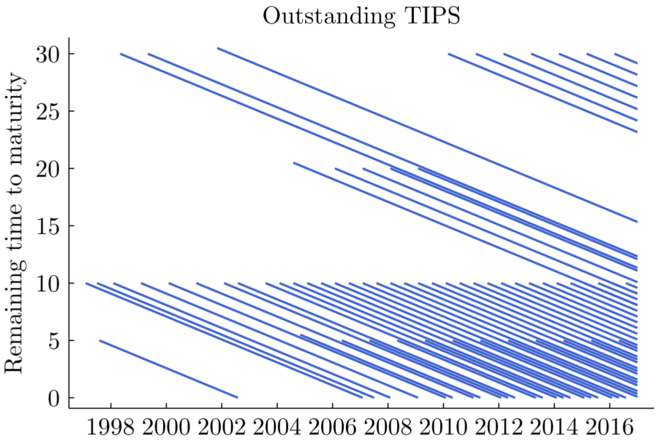
# Estimated effects on real yield curve

▸ Outstanding TIPS ▸ Back

- We regress $\Delta f_t^{(\tau-1,\tau)}$ on $\Delta y_t^{(1)}$:
  - $\Delta$ is one-day change around FOMC meetings 2004–2016.
  - IV: high freq. change in FF future (Jarocinski-Karadi (20)).
- Following Nakamura-Steinsson (18), use high freq. IV because of other news even on FOMC days. ▸ Comparing FOMC vs. non-FOMC days
- Following Jarocinski-Karadi (20), focus on meetings around which IV and S&P 500 return have opposite signs.
- Robustness: ▸ Details
  - Sample: all FOMC meetings, excl. 7/2008–6/2009, excl. LSAP news (Cieslak-Schrimpf (19)).
  - IV: Bauer-Swanson(22), Nakamura-Steinsson(18), Swanson(21).

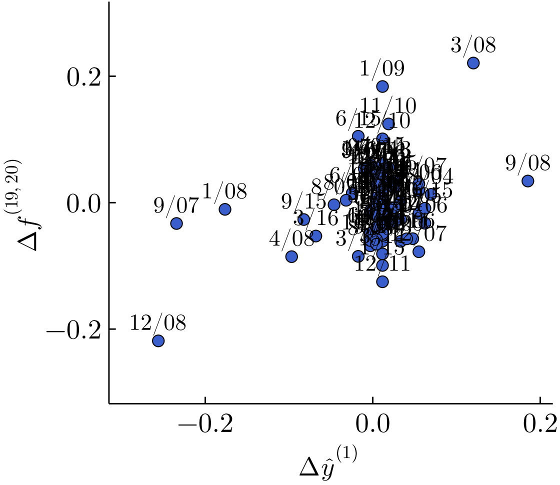
# Outstanding TIPS

Back



# Estimated effects on real yield curve (1/2)

Back

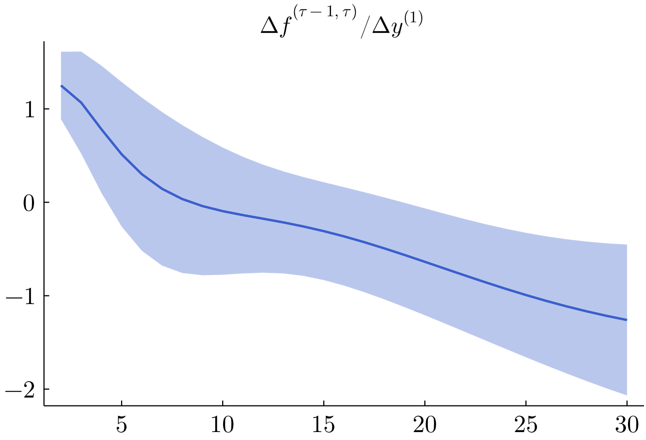


# Estimated effects on real yield curve (2/2) ▸ Back

| Specification | $\Delta f_t^{(4,5)}$ | $\Delta f_t^{(9,10)}$ | $\Delta f_t^{(14,15)}$ | $\Delta f_t^{(19,20)}$ |
|---|---|---|---|---|
| Baseline | 0.40 | 0.11 | 0.25 | 0.39 |
| | (0.10) | (0.14) | (0.15) | (0.14) |
| All FOMC announcements | 0.38 | 0.11 | 0.13 | 0.27 |
| | (0.10) | (0.11) | (0.15) | (0.13) |
| Excl. 7/08-6/09 | 0.46 | -0.26 | 0.21 | 0.50 |
| | (0.22) | (0.30) | (0.21) | (0.29) |
| Excl. announcements with LSAP news | 0.28 | -0.12 | 0.07 | 0.30 |
| | (0.12) | (0.17) | (0.14) | (0.19) |
| Swanson (21) Fed funds IV | 0.31 | 0.15 | 0.30 | 0.41 |
| | (0.13) | (0.13) | (0.16) | (0.17) |
| Swanson (21) forward guidance IV | 1.05 | 0.44 | 0.25 | 0.23 |
| | (0.23) | (0.13) | (0.13) | (0.12) |
| Bauer-Swanson (22) IV | 0.64 | 0.27 | 0.17 | 0.23 |
| | (0.14) | (0.11) | (0.14) | (0.13) |
| Nakamura-Steinsson (18) IV | 0.64 | 0.27 | 0.35 | 0.40 |
| | (0.15) | (0.13) | (0.11) | (0.13) |
| NS (18) IV, excl. 7/08-6/09 | 0.72 | -0.07 | 0.13 | 0.29 |
| | (0.32) | (0.26) | (0.19) | (0.26) |

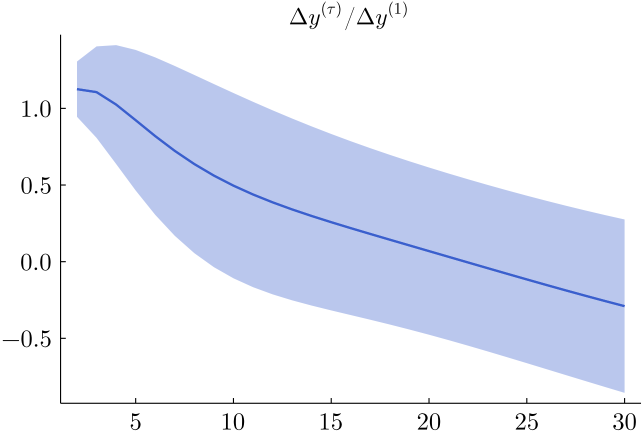
# Estimated effects on nominal yield curve (1/3)

Back



# Estimated effects on nominal yield curve (2/3)

Back



# Estimated effects on nominal yield curve (3/3)

Back

| Specification | $\Delta f_t^{(4,5)}$ | $\Delta f_t^{(9,10)}$ | $\Delta f_t^{(14,15)}$ | $\Delta f_t^{(19,20)}$ |
|---|---|---|---|---|
| Baseline | 0.51 | -0.09 | -0.31 | -0.64 |
| | (0.47) | (0.41) | (0.31) | (0.34) |
| All FOMC announcements | 0.42 | -0.09 | -0.23 | -0.42 |
| | (0.26) | (0.23) | (0.17) | (0.19) |
| Excl. 7/08-6/09 | 0.10 | -0.49 | -0.59 | -0.84 |
| | (0.34) | (0.33) | (0.43) | (0.51) |
| Excl. announcements with LSAP news | -0.02 | -0.52 | -0.51 | -0.74 |
| | (0.30) | (0.27) | (0.35) | (0.40) |
| Swanson (21) Fed funds IV | 0.41 | 0.00 | -0.18 | -0.64 |
| | (0.57) | (0.47) | (0.35) | (0.46) |
| Swanson (21) forward guidance IV | 2.30 | 0.87 | 0.09 | -0.20 |
| | (0.94) | (0.48) | (0.23) | (0.29) |
| Bauer-Swanson (22) IV | 0.87 | 0.15 | -0.20 | -0.50 |
| | (0.36) | (0.30) | (0.22) | (0.28) |
| Nakamura-Steinsson (18) IV | 0.91 | 0.27 | -0.12 | -0.48 |
| | (0.46) | (0.40) | (0.28) | (0.33) |
| NS (18) IV, excl. 7/08-6/09 | 0.27 | -0.29 | -0.37 | -0.66 |
| | (0.29) | (0.29) | (0.32) | (0.41) |

# Estimated arb duration

▸ Over time ▸ Back

- Dealer balance sheets from FA, hedge funds from Form PF.

| | Q4 2012 balance sheet ($bn) | | |
|---|---|---|---|
| | Broker/ dealers | Hedge funds | Sum |
| Cash, deposits, MMFs | 128 | 553 | 681 |
| Repo and other ST loans | -448 | -1,231 | -1,679 |
| Treasuries | 185 | 654 | 839 |
| Corp and foreign bonds | 40 | 994 | 1,034 |
| Other debt securities | 302 | 61 | 363 |
| Loans | -35 | 133 | 99 |
| Corp equities | 127 | 1,148 | 1,275 |
| Wealth | 299 | 2,313 | 2,612 |

# Estimated arb duration

▸ Over time ▸ Back

- Dealer balance sheets from FA, hedge funds from Form PF.
- Duration from Bloomberg indices and Greenwald et al (22).

| | Q4 2012 balance sheet ($bn) | | | |
|---|---|---|---|---|
| | Broker/ dealers | Hedge funds | Sum | Duration (years) |
| Cash, deposits, MMFs | 128 | 553 | 681 | 0.25 |
| Repo and other ST loans | -448 | -1,231 | -1,679 | 0.083 |
| Treasuries | 185 | 654 | 839 | 5.4 |
| Corp and foreign bonds | 40 | 994 | 1,034 | 7.2 |
| Other debt securities | 302 | 61 | 363 | 3.2 |
| Loans | -35 | 133 | 99 | 5 |
| Corp equities | 127 | 1,148 | 1,275 | 35 |
| Wealth | 299 | 2,313 | 2,612 | |

# Estimated arb duration

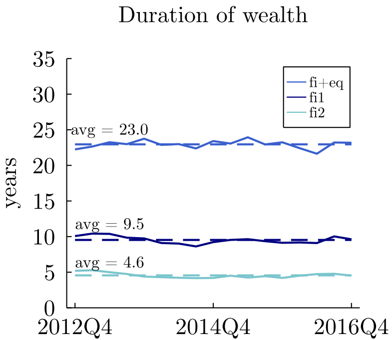
▸ Over time ▸ Back

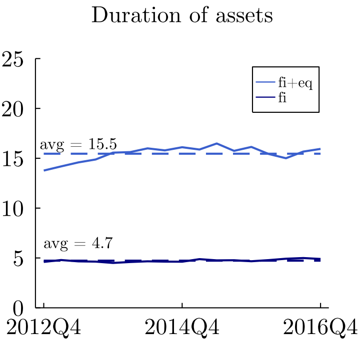
- Dealer balance sheets from FA, hedge funds from Form PF.
- Duration from Bloomberg indices and Greenwald et al (22).
- Estimate duration with/without corporate equities.

| | Q4 2012 balance sheet ($bn) | | | |
|---|---|---|---|---|
| | Broker/ dealers | Hedge funds | Sum | Duration (years) |
| Cash, deposits, MMFs | 128 | 553 | 681 | 0.25 |
| Repo and other ST loans | -448 | -1,231 | -1,679 | 0.083 |
| Treasuries | 185 | 654 | 839 | 5.4 |
| Corp and foreign bonds | 40 | 994 | 1,034 | 7.2 |
| Other debt securities | 302 | 61 | 363 | 3.2 |
| Loans | -35 | 133 | 99 | 5 |
| Corp equities | 127 | 1,148 | 1,275 | 35 |
| Wealth | 299 | 2,313 | 2,612 | 22.2 (fi+eq)<br>10.1 (fi,1)<br>5.2 (fi,2) |

# Estimated arb duration over time

Back



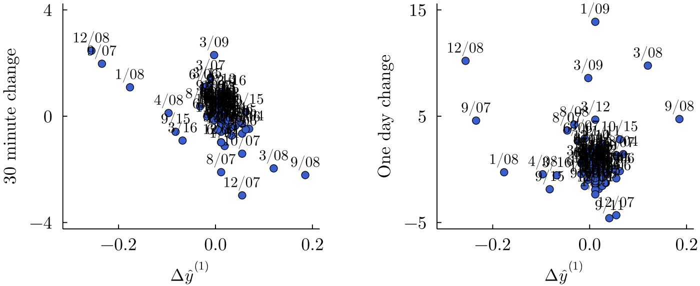




- Average duration of wealth between 4.6-23.0.
- Ignoring repo + ST loans (“duration of assets”), 4.7-15.5.

# Estimated arb duration

▸ List of dealers ▸ Robustness ▸ Back

- Complementary approach: high freq. response of publicly traded dealer stock prices to monetary shocks.




- $1pp$ increase in 1y yield $\Rightarrow$ $9.8pp$ decline in dealer equity prices.

- High freq. window needed for power.

# List of dealers (1/2)

Back

| | CRSP/TAQ | | FR Y9-C | |
|---|---|---|---|---|
| Dealer | Ticker | Availability | RSSD | Availability |
| Bank of America | BAC | 1/2/2004-12/30/2016 | 1073757 | 2004Q1-2016Q4 |
| Barclays | BCS | 1/2/2004-12/30/2016 | 2914521 | 2004Q4-2010Q3* |
| BMO | BMO | 1/2/2004-12/30/2016 | 1245415 | 2004Q1-2016Q4 |
| Bank of Novia Scotia | BNS | 1/2/2004-12/30/2016 | 1238967 | |
| Bear Stearns | BSC | 1/2/2004-5/30/2008 | 1573257 | |
| Citigroup | C | 1/2/2004-12/30/2016 | 1951350 | 2004Q1-2016Q4 |
| CIBC | CM | 1/2/2004-12/30/2016 | 2797498 | 2004Q1-2004Q3 |
| Credit Suisse | CS | 1/2/2004-12/30/2016 | 1574834 | 2016Q3-2016Q4 |
| Deutsche Bank | DB | 1/2/2004-12/30/2016 | 1032473 | 2004Q1-2016Q4* |
| Goldman Sachs | GS | 1/2/2004-12/30/2016 | 2380443 | 2009Q1-2016Q4 |
| HSBC | HSBC | 1/2/2004-12/30/2016 | 3232316 | 2004Q1-2016Q4 |
| Jefferies | JEF | 1/2/2004-2/28/2013 | 2046020 | |
| JP Morgan | JPM | 1/2/2004-12/30/2016 | 1039502 | 2004Q1-2016Q4 |
| Lehman Brothers | LEH | 1/2/2004-9/17/2008 | 2380144 | |

# List of dealers (2/2)

▸ Back

| | CRSP/TAQ | | FR Y9-C | |
|---|---|---|---|---|
| Dealer | Ticker | Availability | RSSD | Availability |
| Merrill Lynch | MER | 1/2/2004-12/31/2008 | | |
| MF Global | MF | 7/19/2007-10/28/2011 | 4236731 | 2016Q3-2016Q4 |
| Mizuho | MFG | 11/8/2006-12/30/2016 | 5034792 | 2016Q3-2016Q4 |
| Morgan Stanley | MS | 1/2/2004-12/30/2016 | 2162966 | 2009Q1-2016Q4 |
| Nomura | NMR | 1/2/2004-12/30/2016 | 1445345 | |
| Banc One | ONE | 1/2/2004-6/30/2004 | 1068294 | 2004Q1-2004Q2 |
| Prudential | PRU | 1/2/2004-12/30/2016 | 2441728 | |
| RBS | RBS | 10/18/2007-12/30/2016 | 1851106 | |
| RBC | RY | 1/2/2004-12/30/2016 | 3226762 | 2010Q4-2016Q4* |
| TD | TD | 1/2/2004-12/30/2016 | 3606542 | 2015Q3-2016Q4 |
| UBS | UBS | 1/2/2004-12/30/2016 | 4846998 | 2016Q3-2016Q4 |
| Wells Fargo | WFC | 1/2/2004-12/30/2016 | 1120754 | 2004Q1-2016Q4 |
| Zions First National | ZION | 1/2/2004-12/30/2016 | 1027004 | 2004Q1-2016Q4 |

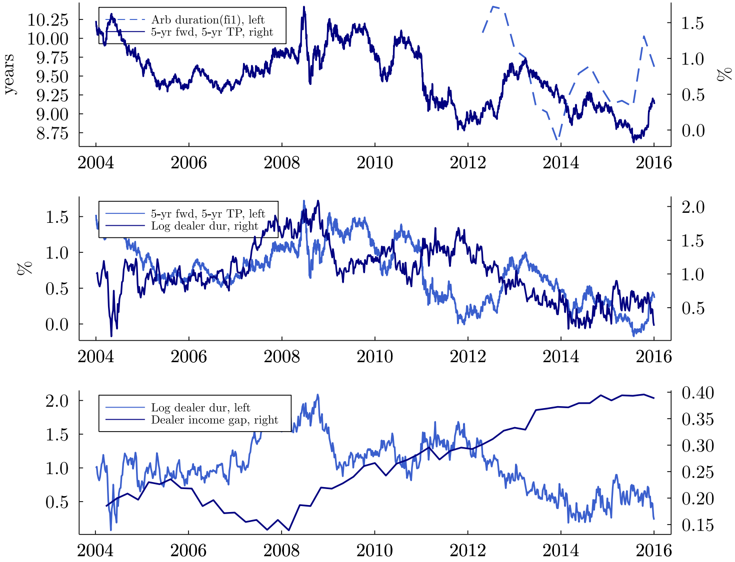
# High frequency response of dealer equities

Back

| Specification | 30 minute change | One day change |
|---|---|---|
| Baseline | -9.8 | -8.0 |
| | (3.2) | (9.9) |
| All FOMC announcements | -1.4 | -2.7 |
| | (4.5) | (8.2) |
| Excl. 7/08-6/09 | -19.4 | -2.6 |
| | (11.2) | (20.0) |
| Excl. announcements with LSAP news | -12.4 | 4.0 |
| | (5.8) | (10.1) |
| Swanson (21) Fed funds IV | -10.0 | -4.2 |
| | (3.6) | (10.5) |
| Swanson (21) forward guidance IV | -11.4 | -13.1 |
| | (5.0) | (5.3) |
| Bauer-Swanson (22) IV | -7.7 | -14.8 |
| | (3.2) | (6.7) |
| Nakamura-Steinsson (18) IV | -12.2 | -21.3 |
| | (4.0) | (6.6) |
| NS (18) IV, excl. 7/08-6/09 | -24.2 | -20.6 |
| | (10.0) | (17.6) |

# Comparing measures of arb duration

▸ Back



# Relating yield curve responses and arb duration

▸ Back

| Specification | 5-yr fwd, 5-yr TP | Log dealer dur. | −Dealer income gap |
|---|---|---|---|
| Baseline | 0.50 | 0.65 | 2.0 |
| | (0.25) | (0.27) | (1.7) |
| All FOMC announcements | 0.11 | 0.31 | 1.4 |
| | (0.43) | (0.24) | (1.7) |
| Excl. 7/08-6/09 | 1.08 | 2.67 | 6.5 |
| | (0.63) | (4.99) | (5.7) |
| Excl. announcements with LSAP news | 0.43 | 0.64 | 1.6 |
| | (0.38) | (0.51) | (1.6) |
| Swanson (21) Fed funds IV | 0.70 | 0.68 | 2.1 |
| | (0.42) | (0.32) | (2.7) |
| Swanson (21) forward guidance IV | 0.08 | 0.15 | 1.4 |
| | (0.20) | (0.23) | (1.7) |
| Bauer-Swanson (22) IV | 0.65 | 0.37 | 2.1 |
| | (0.73) | (0.31) | (2.2) |
| Nakamura-Steinsson (18) IV | 0.56 | 0.72 | 16.2 |
| | (0.55) | (0.37) | (10.2) |
| NS (18) IV, excl. 7/08-6/09 | 1.11 | 2.76 | 14.2 |
| | (0.70) | (4.97) | (9.5) |

# High frequency dealer return in first stage

Back

| Specification | $\Delta f_t^{(4,5)}$ | $\Delta f_t^{(9,10)}$ | $\Delta f_t^{(14,15)}$ | $\Delta f_t^{(19,20)}$ |
|---|---|---|---|---|
| Baseline | -0.041 | -0.011 | -0.025 | -0.040 |
| | (0.018) | (0.016) | (0.017) | (0.016) |
| All FOMC announcements | -0.275 | -0.082 | -0.094 | -0.199 |
| | (0.915) | (0.269) | (0.262) | (0.608) |
| Excl. 7/08-6/09 | -0.024 | 0.013 | -0.011 | -0.025 |
| | (0.020) | (0.010) | (0.012) | (0.017) |
| Excl. announcements with LSAP news | -0.023 | 0.010 | -0.006 | -0.025 |
| | (0.016) | (0.010) | (0.011) | (0.013) |
| Swanson (21) Fed funds IV | -0.031 | -0.015 | -0.030 | -0.041 |
| | (0.019) | (0.016) | (0.016) | (0.017) |
| Swanson (21) forward guidance IV | -0.092 | -0.038 | -0.022 | -0.020 |
| | (0.034) | (0.019) | (0.012) | (0.012) |
| Bauer-Swanson (22) IV | -0.084 | -0.035 | -0.022 | -0.030 |
| | (0.036) | (0.021) | (0.020) | (0.021) |
| Nakamura-Steinsson (18) IV | -0.052 | -0.022 | -0.029 | -0.033 |
| | (0.018) | (0.017) | (0.016) | (0.017) |
| NS (18) IV, excl. 7/08-6/09 | -0.030 | 0.003 | -0.005 | -0.012 |
| | (0.017) | (0.010) | (0.009) | (0.011) |

# High frequency dealer return and duration (1/2) Back

| Specification | 5-yr fwd, 5-yr TP | Log dealer dur. | −Dealer income gap |
|---|---|---|---|
| Baseline | -6.3 | -9.4 | -75.3 |
| | (7.8) | (7.0) | (37.2) |
| All FOMC announcements | 1.6 | 8.5 | -6.9 |
| | (13.3) | (9.1) | (51.8) |
| Excl. 7/08-6/09 | -33.2 | -81.1 | -257.8 |
| | (29.7) | (194.3) | (289.4) |
| Excl. announcements with LSAP news | -13.4 | -17.9 | -81.6 |
| | (10.4) | (14.7) | (51.2) |
| Swanson (21) Fed funds IV | 0.6 | -9.4 | -74.9 |
| | (9.8) | (5.9) | (51.3) |
| Swanson (21) forward guidance IV | -5.0 | -9.0 | -132.7 |
| | (8.5) | (10.9) | (113.1) |
| Bauer-Swanson (22) IV | -9.5 | 0.0 | -51.2 |
| | (8.5) | (6.9) | (44.2) |
| Nakamura-Steinsson (18) IV | 17.5 | -0.0 | -282.2 |
| | (11.2) | (8.0) | (257.9) |
| NS (18) IV, excl. 7/08-6/09 | 1.0 | -89.1 | -296.1 |
| | (14.6) | (232.1) | (365.7) |

# High frequency dealer return and duration (2/2)

▸ Back

| Specification | −Income gap |
|---|---|
| Baseline | -11.8 |
| | (7.9) |
| All FOMC announcements | 1.4 |
| | (10.4) |
| Excl. 7/08-6/09 | -60.8 |
| | (30.4) |
| Excl. announcements with LSAP news | -24.6 |
| | (13.4) |
| Swanson (21) Fed funds IV | -5.0 |
| | (9.4) |
| Swanson (21) forward guidance IV | -22.5 |
| | (12.2) |
| Bauer-Swanson (22) IV | -3.8 |
| | (7.0) |
| Nakamura-Steinsson (18) IV | -4.0 |
| | (9.1) |
| NS (18) IV, excl. 7/08-6/09 | -22.6 |
| | (22.2) |

# Quarterly dealer returns and income gap

Back

| | Dealer return | Dealer return | Dealer return | Dealer return |
|---|---|---|---|---|
| Ex. 5-10 year bond return | -0.69 | 1.55 | -0.69 | 1.55 |
| | (2.31) | (1.24) | (2.34) | (1.24) |
| Lagged income gap | 81.6 | -6.58 | 72.9 | -1.35 |
| | (82.23) | (63.61) | (144.74) | (104.62) |
| Ex. 5-10 year bond return × lagged income gap | -5.99 | -9.51 | -6.02 | -9.49 |
| | (7.12) | (4.10) | (7.22) | (4.10) |
| Ex. S&P 500 return | | 1.35 | | 1.35 |
| | | (0.23) | | (0.24) |
| 3-month Treasury return | | | -0.64 | 0.39 |
| | | | (5.76) | (3.76) |
| $N$ | 52 | 52 | 52 | 52 |
| $R^2$ | 0.35 | 0.67 | 0.35 | 0.67 |

# PDE

Back

$$
\begin{aligned}
&\Big[P^{(\tau)}_{r,\,t}\kappa_r\left(\bar{r}-r_t\right)+P^{(\tau)}_{W,\,t}\omega_t+P^{(\tau)}_{\beta,\,t}\kappa_\beta\left(\bar{\beta}-\beta_t\right)-P^{(\tau)}_{\tau,\,t}+\frac{1}{2}P^{(\tau)}_{rr,\,t}\sigma_r^2\\
&+\frac{1}{2}P^{(\tau)}_{WW,\,t}\left(\eta^2_{r,\,t}+\eta^2_{\beta,\,t}\right)+\frac{1}{2}P^{(\tau)}_{\beta\beta,\,t}\sigma^2_\beta+P^{(\tau)}_{rW,\,t}\sigma_r\eta_{r,\,t}+P^{(\tau)}_{\beta W,\,t}\sigma_\beta\eta_{\beta,\,t}-r_tP^{(\tau)}_t\Big]\,dt\\
&=\frac{1}{W_t}\Bigg[\left(P^{(\tau)}_{r,\,t}\sigma_r+P^{(\tau)}_{W,\,t}\eta_{r,\,t}\right)\int_0^\infty\left(\alpha(s)\log\left(P^{(s)}_t\right)+\theta_0(s)\right)\frac{1}{P^{(s)}_t}\left(P^{(s)}_{r,\,t}\sigma_r+P^{(s)}_{W,\,t}\eta_{r,\,t}\right)ds\\
&+\left(P^{(\tau)}_{\beta,\,t}\sigma_\beta+P^{(\tau)}_{W,\,t}\eta_{\beta,\,t}\right)\int_0^\infty\left(\alpha(s)\log\left(P^{(s)}_t\right)+\theta_0(s)\right)\frac{1}{P^{(s)}_t}\left(P^{(s)}_{\beta,\,t}\sigma_\beta+P^{(s)}_{W,\,t}\eta_{\beta,\,t}\right)ds\\
&+\beta_t\Bigg[\left(P^{(\tau)}_{r,\,t}\sigma_r+P^{(\tau)}_{W,\,t}\eta_{r,\,t}\right)\int_0^\infty\theta_1(s)\frac{1}{P^{(s)}_t}\left(P^{(s)}_{r,\,t}\sigma_r+P^{(s)}_{W,\,t}\eta_{r,\,t}\right)ds\\
&+\left(P^{(\tau)}_{\beta,\,t}\sigma_\beta+P^{(\tau)}_{W,\,t}\eta_{\beta,\,t}\right)\int_0^\infty\theta_1(s)\frac{1}{P^{(s)}_t}\left(P^{(s)}_{\beta,\,t}\sigma_\beta+P^{(s)}_{W,\,t}\eta_{\beta,\,t}\right)ds\Bigg]\Bigg]\,dt.
\end{aligned}
$$

# Wealth process

Back

$$dW_t = \omega(r_t, \beta_t, W_t)dt + \eta_r(r_t, \beta_t, W_t)dB_{r,\,t} + \eta_\beta(r_t, \beta_t, W_t)dB_{\beta,\,t}$$

where

$$\omega_t = \xi\left(\bar{W} - W_t\right) + W_t r_t + \int_0^\infty \left(\alpha(\tau)\log\left(P_t^{(\tau)}\right) + \theta_0(\tau) + \theta_1(\tau)\beta_t\right)\left(\mu_t^{(\tau)} - r_t\right) d\tau$$

$$\eta_{r,\,t} = \int_0^\infty \left(\alpha(\tau)\log\left(P_t^{(\tau)}\right) + \theta_0(\tau) + \theta_1(\tau)\beta_t\right)\frac{1}{P_t^{(\tau)}}\left(P_{r,\,t}^{(\tau)}\sigma_r + P_{W,\,t}^{(\tau)}\eta_{r,\,t}\right) d\tau$$

$$\eta_{\beta,\,t} = \int_0^\infty \left(\alpha(\tau)\log\left(P_t^{(\tau)}\right) + \theta_0(\tau) + \theta_1(\tau)\beta_t\right)\frac{1}{P_t^{(\tau)}}\left(P_{\beta,\,t}^{(\tau)}\sigma_\beta + P_{W,\,t}^{(\tau)}\eta_{\beta,\,t}\right) d\tau.$$

# QE purchases in data (1/2)

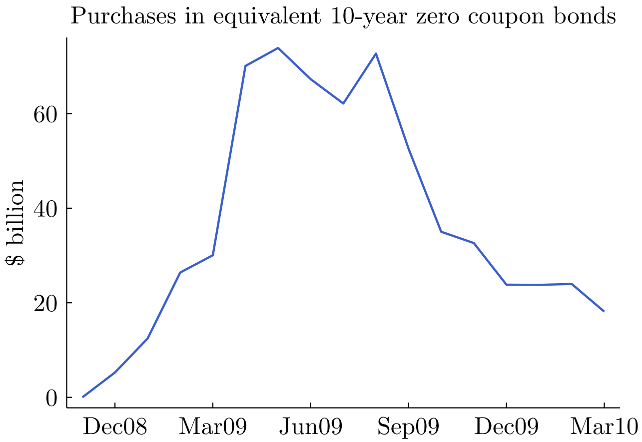
Back

- CUSIP-level Treasuries and agency debt purchases from SOMA,
  agency MBS purchases from Fed Board.
- Transform purchases into panel dataset of purchases of ZCBs purchased at each maturity $\tau \in (0, 30]$ on each date $t$:
  - Treasuries and agency debt: strip and compute market values using ZCB yield curve.
  - MBS: assume ZCB with maturity = effective duration of Bloomberg MBS index.

$\Rightarrow$ Over \$600bn in ten-year equivalent ZCBs purchased in QE1.

# QE purchases in data (2/2)

Back



# QE price impact in data

Back

| | $\Delta y_t^{(10)}$ | $\Delta y_t^{(20)}$ | $\Delta f_t^{(10)}$ | $\Delta f_t^{(20)}$ |
|---|---|---|---|---|
| 11/25/2008 | -39 | -19 | -48 | 22 |
| 12/1/2008 | -34 | -39 | -10 | -98 |
| 12/16/2008 | -58 | -39 | -31 | -17 |
| 1/28/2009 | 9 | 14 | 16 | 21 |
| 3/18/2009 | -61 | -41 | -46 | -25 |
| Sum to date | -183 | -124 | -119 | -98 |
| 8/12/2009 | -0 | -0 | -1 | -1 |
| 9/23/2009 | -1 | 1 | 1 | 4 |
| 11/4/2009 | -3 | -6 | 2 | -6 |
| Sum to date | -188 | -129 | -117 | -100 |

# Arb wealth from Q407 to Q109

Back

| | Q4 2007 | Q1 2009 | Percent change |
|---|---|---|---|
| Broker/dealers | 285 | 293 | 3 |
| Hedge funds: distressed securities | 176 | 69 | -61 |
| Hedge funds: fixed income | 160 | 69 | -57 |
| Hedge funds: macro | 91 | 61 | -33 |
| Broker/dealers + core FI hedge funds | 712 | 492 | -31 |
| Hedge funds: convertible arbitrage | 42 | 11 | -74 |
| Hedge funds: emerging markets | 353 | 125 | -65 |
| Hedge funds: equity strategies | 538 | 303 | -44 |
| Hedge funds: event-driven | 162 | 57 | -65 |
| Hedge funds: merger arbitrage | 39 | 5 | -87 |
| Hedge funds: multistrategy | 224 | 122 | -46 |
| Hedge funds: other | 61 | 20 | -67 |
| Hedge funds: sector specific | 130 | 58 | -55 |
| Broker/dealers + hedge funds | 2,261 | 1,193 | -47 |

# Simulating QE in model (1/2)

Back

- Focus on 3/18/09 surprise: all Treasuries, \$100bn agency debt, \$750bn MBS.
- Translate purchases into model scale:
  - Over 2012-16, arb wealth 9% of GDP (next slide).

  $\Rightarrow$ In month 0, agents learn $\theta_t(\tau)$ will fall by

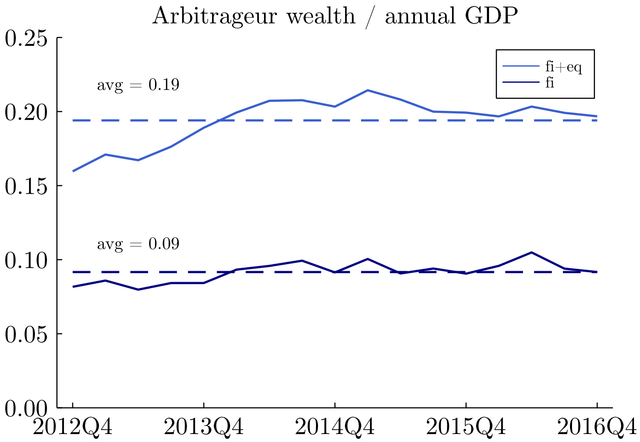
$$\frac{\text{purchases}(\tau)_t}{\text{gdp}_{2007}} \frac{W}{0.09},$$

  where $\text{purchases}(\tau)_t$ is $t$ months after 4/09, $\text{gdp}_{2007}$ is annual GDP prior to crisis, and $W$ is average value of arbitrageur wealth in model.

- Simulate in model starting from $\{r = \bar{r}, \beta = 0, W_0 = 0.6W\}$.

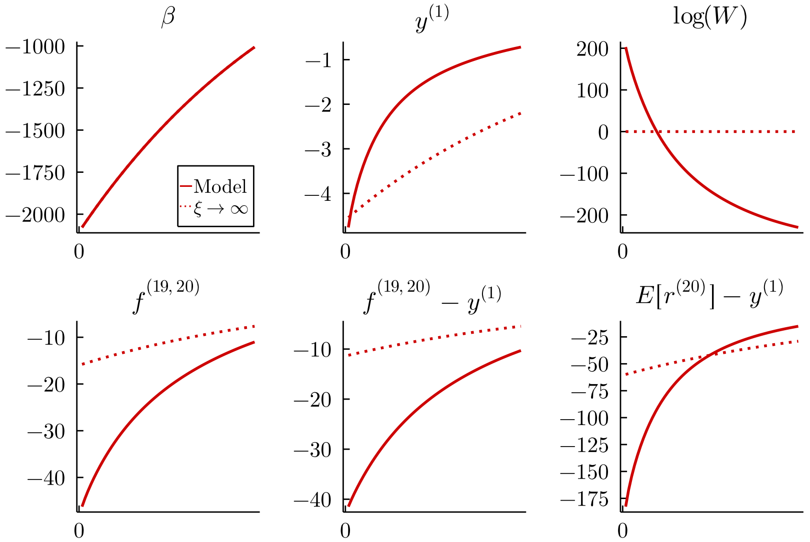
# Simulating QE in model (2/2)

Back



# Habitat demand shock

Back



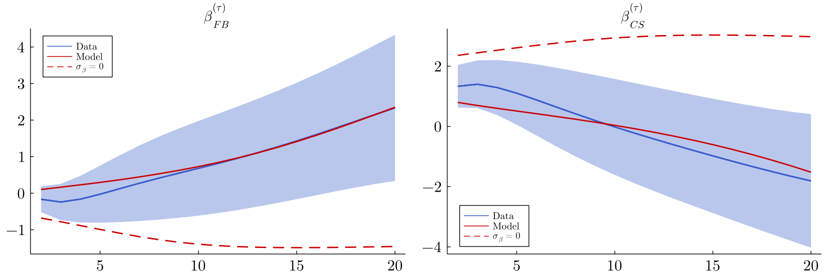
# Calibration: details

Fama-Bliss (87) and Campbell-Shiller (91) coefficients Back

| | Description | Value | Moment | Target | Model |
|---|---|---|---|---|---|
| *Unconditional moments of yields* | | | | | |
| $\bar{r}$ | mean short rate | -0.0024 | $y_t^{(1)}$ | 0.06% | 0.06% |
| $\kappa_r$ | mean rev. short rate | 0.42 | $\sigma(y_t^{(1)})$ | 1.66% | 1.67% |
| $\sigma_r$ | std. dev. short rate | 0.023 | $\sigma(\Delta y_{t+1}^{(1)})$ | 1.75% | 1.74% |
| $\kappa_\beta$ | mean rev. demand | 0.15 | $\beta_{FB}^{(10)}$ | 0.68 | 0.73 |
| $\sigma_\beta$ | std. dev. demand | 0.72 | $\beta_{FB}^{(20)}$ | 2.34 | 2.35 |
| $\xi$ | persistence arb. wealth | 0.07 | $y_t^{(20)} - y_t^{(1)}$ | 1.54% | 1.61% |
| *Duration of arbitrageurs* | | | | | |
| $\bar{W}$ | arb. endowment | 0.01 | wealth duration | 9.5 | 9.8 |
| $\delta$ | shape habitat demand | 0.19 | asset duration | 4.7 | 4.8 |
| *Yield curve responses to QE announcement on 3/18/09* | | | | | |
| $\alpha$ | habitat price elast. | 1 | $df_t^{(19,20)}$ | -0.25% | -0.26% |

# Bond return predictability

Back




- Model also consistent with FB (87), CS (91) evidence:

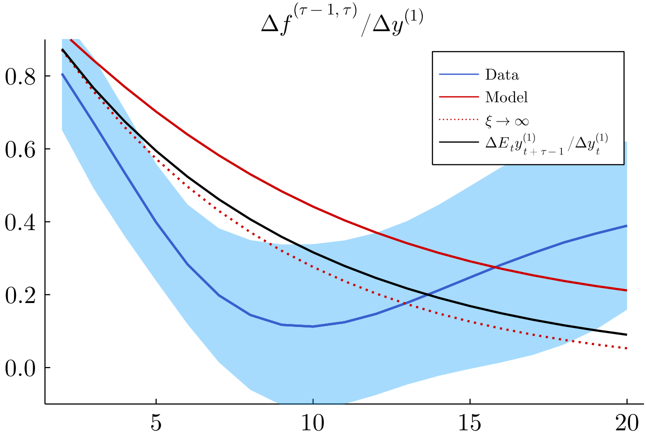
$$r^{(\tau)}_{t+1} - y^{(1)}_t = \alpha^{(\tau)}_{FB} + \beta^{(\tau)}_{FB}\left(f^{(\tau-1,\tau)}_t - y^{(1)}_t\right) + \epsilon^{(\tau)}_{FB,t+1},$$

$$y^{(\tau-1)}_{t+1} - y^{(\tau)}_t = \alpha^{(\tau)}_{CS} + \beta^{(\tau)}_{CS}\frac{1}{\tau-1}\left(y^{(\tau)}_t - y^{(1)}_t\right) + \epsilon^{(\tau)}_{CS,t+1}.$$

- Relies on demand shocks (indeed, disciplines $\sigma_r$, $\kappa_r$).

# More persistent short rate shock

Back




- Set $\kappa_r = 0.125$ as in nominal calibration of VV (21).
- Amplified underreaction if $\xi \to \infty$, but overreaction in model.

# Cochrane-Piazzesi decomposition

Back

- As derived in Cochrane-Piazzesi (08),

$$f_t^{(\tau-1,\tau)} - y_{t+\tau-1}^{(1)} =$$
$$\left[r_{t+1}^{(\tau)} - r_{t+1}^{(\tau-1)}\right] + \left[r_{t+2}^{(\tau-1)} - r_{t+2}^{(\tau-2)}\right] + \ldots + \left[r_{t+\tau-1}^{(2)} - y_{t+\tau-2}^{(1)}\right],$$

where

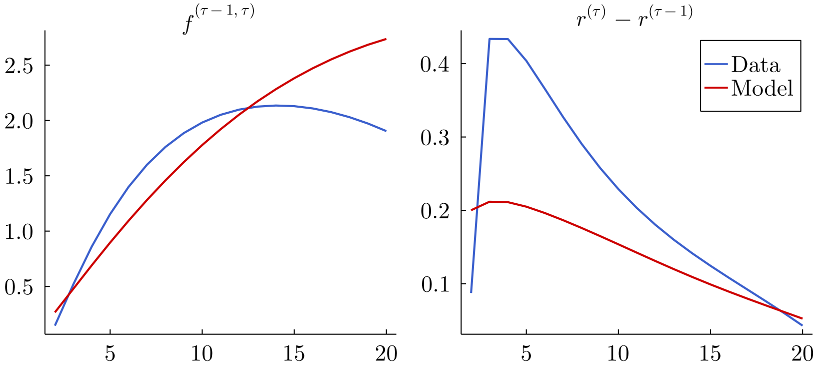
$$r_{t+1}^{(\tau)} \equiv \log P_{t+1}^{(\tau-1)} - \log P_t^{(\tau)}.$$

- Ex-ante, this implies

$$f_t^{(\tau-1,\tau)} - E_t y_{t+\tau-1}^{(1)} =$$
$$E_t\left[r_{t+1}^{(\tau)} - r_{t+1}^{(\tau-1)}\right] + E_t\left[r_{t+2}^{(\tau-1)} - r_{t+2}^{(\tau-2)}\right] + \ldots + E_t\left[r_{t+\tau-1}^{(2)} - y_{t+\tau-2}^{(1)}\right].$$

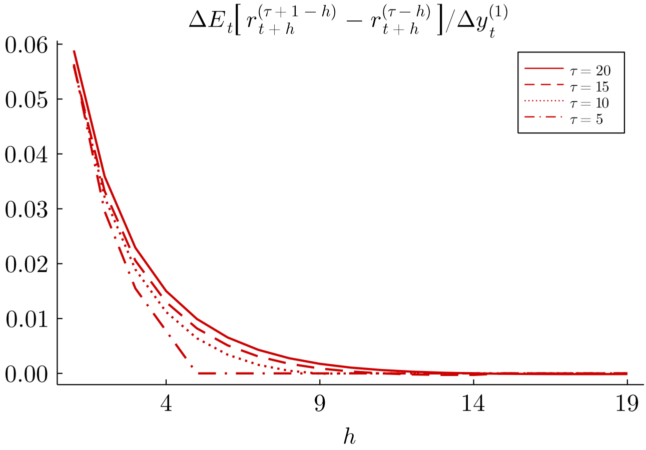
# Forward curve and excess returns

Back



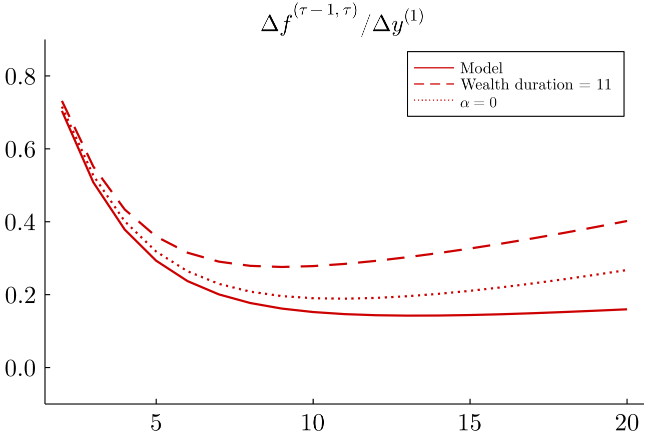
# Decomposing forward rate response

Back



# Monetary shock: sensitivity

Back

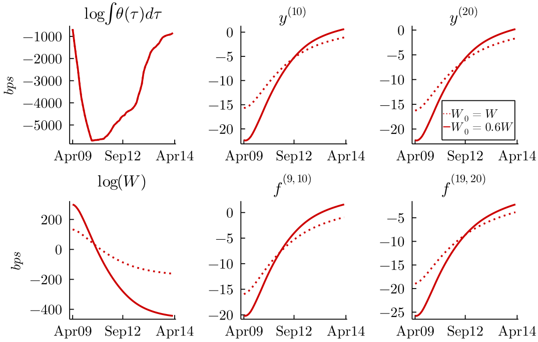



- Fully account for $f^{(19,20)}$ given higher duration and/or lower $\alpha$.
- "Reach for yield" suggests lower $\alpha$ conditional on $r$ shock.

# State-dependent effects of QE

▸ Back

- Reconsider 3/18/09 announcement but set $W_0$ to avg level:




- Long-dated yields, forwards fall by $20 - 30\%$ less:
  - More elastic demand (recall $\frac{d \log P_t}{d\theta_t} = -\frac{1}{\alpha + \frac{W_t}{\sigma_r^2}}$).
  - Lower duration and thus recapitalization from QE.

# Bond price volatility

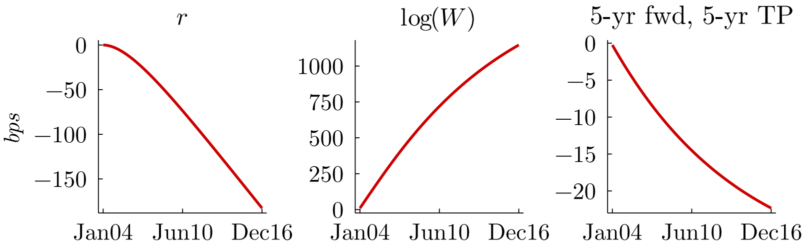
Back

| Moment | Model | $\xi \to \infty$ |
|---|---|---|
| $\sigma(y_t^{(2)})$ | 1.44% | 1.35% |
| $\sigma(y_t^{(5)})$ | 1.10% | 0.84% |
| $\sigma(y_t^{(10)})$ | 1.04% | 0.49% |
| $\sigma(y_t^{(20)})$ | 1.20% | 0.26% |
| $y_t^{(20)} - y_t^{(1)}$ | 1.61% | 0.16% |
| $\sigma(\sigma_{t-1}(y_t^{(20)}))$ | 0.27% | 0% |

- Setting $\xi \to \infty$ while recalibrating $\bar{W}$ to match average $W$:
  - long-dated bond price vol. falls by more than half, so average slope of yield curve substantially flattens;
  - no longer any stochastic vol. in bond prices.

# Secular decline in natural rate

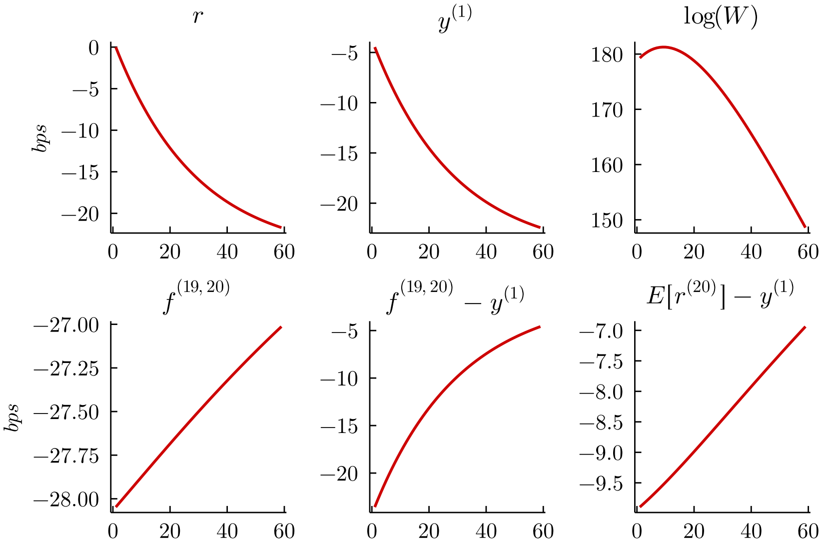
▸ $\bar{r}$ shock ▸ Back




- Decline in $\bar{r}$ from Laubach-Williams (2003) / FRB NY.
- Decline recapitalizes arbs and accounts for $>$ 20% of decline in term premium from D'Amico-Kim-Wei (2018) / Fed Board.
- Complements explanations focused on changing comovements.

# $\bar{r}$ shock

Back



# Comparing FOMC vs. non-FOMC days (1/3) ▸ Back

- Alternative approach to studying effects of monetary policy on yield curve considered in literature:

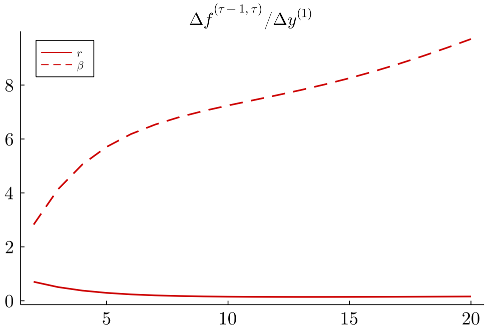
| | $\Delta f_t^{(4,5)}$ | $\Delta f_t^{(9,10)}$ | $\Delta f_t^{(14,15)}$ | $\Delta f_t^{(19,20)}$ |
|---|---|---|---|---|
| $\Delta y_t^{(1)}$ | 0.11 | -0.01 | 0.01 | 0.11 |
| | (0.02) | (0.02) | (0.02) | (0.02) |
| $FOMC_t$ | -0.01 | -0.00 | -0.00 | -0.00 |
| | (0.01) | (0.01) | (0.01) | (0.01) |
| $\Delta y_t^{(1)} \times FOMC_t$ | 0.25 | 0.14 | 0.00 | -0.04 |
| | (0.14) | (0.11) | (0.08) | (0.06) |
| $N$ | 3,252 | 3,252 | 3,252 | 3,252 |
| $R^2$ | 0.07 | 0.00 | 0.00 | 0.03 |

- Small (even negative) interaction coefficients suggest monetary tightening does not raise (and may reduce) long forward rates.

# Comparing FOMC vs. non-FOMC days (2/3) ▸ Back

- Model clarifies two reasons why this is incorrect.
- Underlying reason: $\beta$ shocks have small effect on short yields.

1. Estimated interaction coefficients will be *negative* even though monetary tightening raises term premia:



# Comparing FOMC vs. non-FOMC days (3/3) Back

2. Estimated interaction coefficients will be *small* unless proportion of $r$ vs. $\beta$ shocks change massively on FOMC days:

| $\sigma_r$ | $\Delta f_t^{(4,5)}$ | $\Delta f_t^{(9,10)}$ | $\Delta f_t^{(14,15)}$ | $\Delta f_t^{(19,20)}$ |
|---|---|---|---|---|
| Baseline | 0.37 | 0.23 | 0.22 | 0.24 |
| 1.2 $\times$ Baseline | 0.35 | 0.21 | 0.19 | 0.20 |