Turnover Liquidity and the Transmission of Monetary Policy

Ricardo Lagos Shengxing Zhang

New York University London School of Economics

Two questions

- What is the effect of monetary policy on the stock market?

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- What is the mechanism?

What we do

Theory

- Develop a model of monetary exchange in financial markets
- Study the effects of monetary policy on returns and financial liquidity

Evidence

Estimate the impact of monetary policy on returns and turnover:

- Marketwide
- Across stocks with different liquidity

Quantitative Theory

- Calibrate and simulate model to quantify the theoretical mechanism

Theoretical results

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1. Determine asset prices and standard measures of financial liquidity (trade volume, dealer supply of immediacy, spreads)

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   tight money increases opportunity cost of holding nominal assets routinely used to settle financial transactions (money, bank reserves)

   $\Rightarrow$ nominal assets become scarcer
   $\Rightarrow$ reduced resalability of stocks
   $\Rightarrow$ stock turnover falls
   $\Rightarrow$ stock price falls

Empirical findings

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   ... relative to the class of stocks with median liquidity:
   - Return of top 5% most liquid falls 2 times more
   - Turnover of top 5% most liquid falls 2-3 times more

Quantitative results

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1. Sign and 26% to 60% of the response of stock returns
2. Sign, persistence, modest part of initial response of turnover
3. Relative magnitude of responses of returns and turnover across liquidity classes

Monetary policy and asset prices: related theoretical work

Inflation, liquidity, and asset prices

Lagos (2010, 2011), Lester, Postlewaite and Wright (2012), Nosal and Rocheteau (2013), Piazzesi and Schneider (2016)

Money in OTC financial markets

Lagos and Zhang (2014), Geromichalos and Herrenbrueck (2016), Nosal and Mattesini (2016), Trejos and Wright (2016)

Speculative bubbles

Harrison and Kreps (1978), Scheinkman and Xiong (2003)

Monetary policy and asset prices: related empirical work

Event-study methodology

Cook and Hahn (1989), Thorbecke (1997), Kuttner (2001), Cochrane and Piazzesi (2002), Bernanke and Kuttner (2005), Hanson and Stein (2015)

High-frequency identification

Gürkaynak, Sack and Swanson (2005), Gertler and Karadi (2015), Gorodnichenko and Weber (2015), Nakamura and Steinsson (2015)

Heteroskedasticity-based identification

Rigobon and Sack (2004)

Role of firm characteristics

Ehrmann and Fratzscher (2004), Bernanke and Kuttner (2005), Gorodnichenko and Weber (2015), Ippolito, Ozdagli and Perez (2013)

Environment

- *Time.* Discrete, infinite horizon, two subperiods per period
- *Population.* $[0, 1]$ investors (infinitely lived)
- *Commodities.* Two divisible, nonstorable consumption goods:
    - *dividend good*
    - *general good*

Preferences

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\varepsilon_t y_t + c_t - h_t\right)$$

- $\beta \in (0,1)$: discount factor
- c_t : consumption of general good
- h_t : effort to produce general good
- y_t : consumption of dividend good
- ε_t : valuation shock, i.i.d. over time, cdf $G(\cdot)$ on $[\varepsilon_L, \varepsilon_H]$

Endowments and production technology

First subperiod

A^s productive units (*trees*)

- Each unit yields y_t dividend goods *at the end of the first subperiod*
  $y_t = \gamma_t y_{t-1}$, where $\gamma_t \sim$ i.i.d. with $\mathbb{E}(\gamma_t) = \bar{\gamma}$
- Each unit permanently "fails" with probability $1 - \delta$
  at the beginning of the period
- Failed units immediately replaced by new units
  (allocated uniformly to investors)

Second subperiod

- Linear technology to transform effort into general goods

Assets

Equity shares

- A^s equity shares
- At the beginning of period t:
  - $(1-\delta)\,A^s$ shares of failed trees disappear
  - $(1-\delta)\,A^s$ shares of new trees allocated uniformly to investors

Fiat money

- Money supply: A_t^m dollars
- Monetary policy: $A_{t+1}^m = \mu A_t^m$, $\mu \in \mathbb{R}_{++}$
  (implemented with lump-sum injections/withdrawals)

Market structure

First subperiod: OTC market

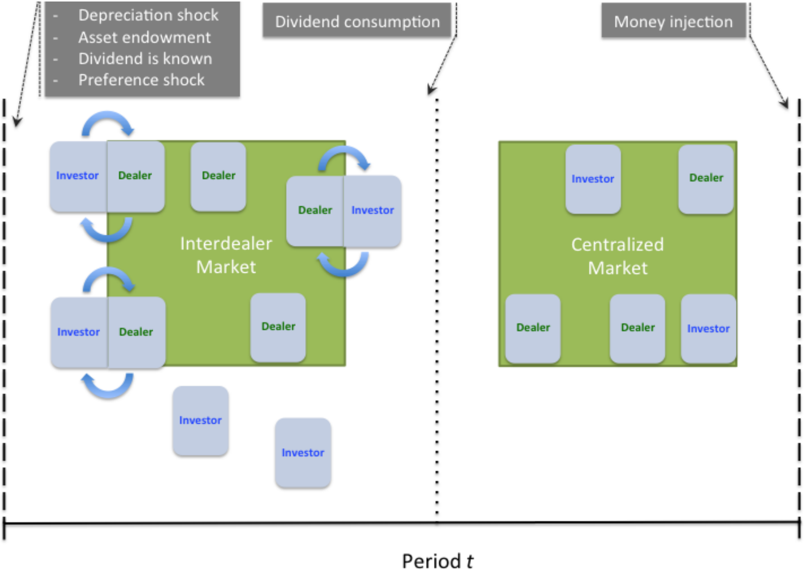
- Money, equity (*cum dividend*)
- Random access to a Walrasian market (with probability α)

Second subperiod: centralized market

- Money, equity (*ex dividend*), general good
- Walrasian trade between all agents

"Anonymity" $\Rightarrow$ *quid pro quo* $\Rightarrow$ money used to pay for assets

Timeline and marketstructure



Value functions

$$W_t^l(\mathbf{a}_t) = \max_{c_t, h_t, \tilde{\mathbf{a}}_{t+1}} \left[c_t - h_t + \beta \int V_{t+1}^l(\mathbf{a}_{t+1}, \varepsilon') \, dG(\varepsilon') \right]$$

$$\mathbf{a}_{t+1} = \left(\tilde{a}_{t+1}^m, \delta \tilde{a}_{t+1}^s + (1-\delta) A^s\right)$$

$$c_t + \boldsymbol{\phi}_t \tilde{\mathbf{a}}_{t+1} \leq h_t + \boldsymbol{\phi}_t \mathbf{a}_t + T_t$$

$\boldsymbol{\phi}_t = (\phi_t^m, \phi_t^s)$: real prices of money and stock

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$\boldsymbol{\phi}_t = (\phi_t^m, \phi_t^s)$: real prices of money and stock

$$V_t^l(\mathbf{a}_t, \varepsilon) = \alpha \left\{ \varepsilon y_t \bar{a}_t^s(\mathbf{a}_t, \varepsilon) + W_t^l\left[\bar{\mathbf{a}}_t(\mathbf{a}_t, \varepsilon)\right] \right\} + (1-\alpha) \left[\varepsilon y_t a_t^s + W_t^l(\mathbf{a}_t) \right]$$

Portfolio problem in OTCM

Investor with portfolio $\mathbf{a}_t = (a_t^m, a_t^s)$ and valuation ε solves

$$\max_{\overline{\mathbf{a}}_t} \left[\varepsilon y_t \overline{a}_t^s + W_t^I (\overline{\mathbf{a}}_t) \right]$$

$$\overline{a}_t^m + p_t \overline{a}_t^s \leq a_t^m + p_t a_t^s$$

p_t : nominal equity price in the OTC interdealer market

OTCM post trade portfolio

$$\overline{a}_t^s = \begin{cases} a_t^s + \frac{1}{p_t} a_t^m & \text{if } \varepsilon_t^* < \varepsilon \\ 0 & \text{if } \varepsilon < \varepsilon_t^* \end{cases}$$

$$\overline{a}_t^m = \begin{cases} 0 & \text{if } \varepsilon_t^* < \varepsilon \\ a_t^m + p_t a_t^s & \text{if } \varepsilon < \varepsilon_t^* \end{cases}$$

where

$$\varepsilon_t^* \equiv \frac{p_t \phi_t^m - \phi_t^s}{y_t}$$

Euler equations

$$\phi_t^m \geq \beta \mathbb{E}_t \left[\phi_{t+1}^m + \alpha\theta \int_{\varepsilon_{t+1}^*}^{\varepsilon_H} \left(\frac{\varepsilon y_{t+1} + \phi_{t+1}^s}{p_{t+1}} - \phi_{t+1}^m \right) dG(\varepsilon) \right]$$

Euler equations

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$$\begin{aligned} \phi_t^s \quad \geq \quad & \beta\delta \mathbb{E}_t \Bigg[\bar{\varepsilon} y_{t+1} + \phi_{t+1}^s \\ & + \alpha\theta \int_{\varepsilon_L}^{\varepsilon_{t+1}^*} \left[p_{t+1}\phi_{t+1}^m - \left(\varepsilon y_{t+1} + \phi_{t+1}^s \right) \right] dG\left(\varepsilon\right) \Bigg] \end{aligned}$$

Friedman rule

Proposition

The allocation implemented by the stationary monetary equilibrium converges to the symmetric efficient allocation as $\mu \to \bar{\beta} \equiv \beta\bar{\gamma}$.

Nonmonetary equilibrium

Proposition

(i) A nonmonetary equilibrium exists for any parametrization.

(ii) In the nonmonetary equilibrium:

- *there is no trade in the OTC market*
- *the equity price is:*

$$\phi_t^s = \frac{\bar{\beta}\delta}{1-\bar{\beta}\delta}\bar{\varepsilon}y_t.$$

Monetary equilibrium

Proposition

(i) If $\mu \in (\bar{\beta}, \bar{\mu})$*, there is one stationary monetary equilibrium.*

(ii) For any $\mu \in (\bar{\beta}, \bar{\mu})$*, there exists a unique* $\varepsilon^* \in (\varepsilon_L, \varepsilon_H)$*.*

(iv) As $\mu \to \bar{\beta}$*,* $\varepsilon^* \to \varepsilon_H$ *and* $\phi_t^s \to \frac{\bar{\beta}\delta}{1-\bar{\beta}\delta}\varepsilon_H y_t$*.*

Stationary monetary equilibrium: allocations

$$\phi_t^s = \phi^s y_t$$

$$\phi^s \equiv \frac{\bar{\beta}\delta}{1-\bar{\beta}\delta}\left[\bar{\varepsilon} + \alpha\theta \int_{\varepsilon_L}^{\varepsilon^*} (\varepsilon^* - \varepsilon)\, dG(\varepsilon)\right]$$

$$\phi_t^m A_t^m = \frac{\alpha G(\varepsilon^*) A^s}{\alpha\left[1 - G(\varepsilon^*)\right]} (\varepsilon^* + \phi^s)\, y_t$$

Asset prices and the nominal interest rate

Proposition

In the stationary monetary equilibrium: $\partial\phi^s/\partial\mu < 0$

The nominal interest rate is:

$$r = \frac{\mu - \bar{\beta}}{\bar{\beta}}$$

Trade volume and the nominal interest rate

$$\mathcal{V} = \alpha G(\varepsilon^*) A^s$$

Proposition

In the stationary monetary equilibrium: $\partial \mathcal{V} / \partial \mu < 0$

The turnover-liquidity transmission mechanism

$$\mathcal{V} = \alpha G(\varepsilon^*) A^s$$

$$\phi^s = \frac{\bar{\beta}\delta}{1-\bar{\beta}\delta}\left[\bar{\varepsilon} + \alpha\theta \int_{\varepsilon_L}^{\varepsilon^*} (\varepsilon^* - \varepsilon)\, dG(\varepsilon)\right]$$

The turnover-liquidity transmission mechanism

$$\mathcal{V} = \alpha G\left(\varepsilon^{*}\right) A^{s}$$

$$\frac{\partial \mathcal{V}}{\partial \mu} = \mathcal{V}\frac{G'\left(\varepsilon^{*}\right)}{G\left(\varepsilon^{*}\right)}\frac{\partial \varepsilon^{*}}{\partial \mu} < 0$$

$$\phi^{s} = \frac{\bar{\beta}\delta}{1-\bar{\beta}\delta}\left[\bar{\varepsilon} + \alpha\theta\int_{\varepsilon_{L}}^{\varepsilon^{*}}\left(\varepsilon^{*}-\varepsilon\right)dG(\varepsilon)\right]$$

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The turnover-liquidity transmission mechanism

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$$\frac{\partial \mathcal{V}}{\partial \mu} = \mathcal{V} \frac{G'(\varepsilon^*)}{G(\varepsilon^*)} \frac{\partial \varepsilon^*}{\partial \mu} < 0$$

$$\frac{\partial \phi^s}{\partial \mu} = \mathcal{V} \frac{\bar{\beta}\delta\theta}{(1-\bar{\beta}\delta) A^s} \frac{\partial \varepsilon^*}{\partial \mu} < 0$$

Preview of empirical work

- Aggregate announcement-day effects
  - Event-study regression
  - Estimation based on heteroskedasticity-based identification
  - High-frequency instrumental variable regression
- Disaggregative announcement-day effects
  - Regressions on portfolios sorted on turnover liquidity
  - Regression with panel data on individual stocks
  - Regressions on portfolios sorted on liquidity betas
- Dynamic effects
  (VAR identified with external high-frequency instrument)
  - VAR with aggregate data
  - VARs on portfolios sorted on turnover liquidity

Data

- Returns
  - stock s on day t: $\mathcal{R}_t^s = \left[\left(P_t^s + D_t^s \right) / P_{t-1}^s - 1 \right] \times 100$
  - aggregate: $\mathcal{R}_t^I = \frac{1}{n} \sum_{s=1}^{n} \mathcal{R}_t^s$
- Volume
  - turnover rate for stock s on day t: $\mathcal{T}_t^s = \mathcal{V}_t^s / A_t^s$
    $\mathcal{V}_t^s$: # of shares traded; A_t^s: # of outstanding shares
  - aggregate: $\mathcal{T}_t^I = \frac{1}{n} \sum_{s=1}^{n} \mathcal{T}_t^s$
- Proxies for the policy rate
  - 3-month Eurodollar futures rate (CME Group)
  - tick-by-tick 30-day fed funds futures rate (CME Group)
- Sample
  - all common stocks in NYSE (1300-1800 stocks, from CRSP)
  - 1994-2001, 2014 trading days, 73 FOMC announcement dates

Event-study (Bernanke and Kuttner, 2005)

$$Y_t = a + b\Delta i_t + \varepsilon_t$$

- $\Delta i_t \equiv i_t - i_{t-1}$: proxy for unexpected change in policy rate
- i_t : day-t nominal interest rate implied by 3-month Eurodollar futures with closest expiration after day t
- $t \in S_1$ (sample of 73 FOMC policy announcement days)
- Regression 1: $Y_t = \mathcal{R}_t^l$
- Regression 2: $Y_t = \mathcal{T}_t^l - \mathcal{T}_{t-1}^l$

Heteroskedasticity-based (Rigobon and Sack, 2004)

$$Y_t = \alpha \Delta i_t + X_t + \varepsilon_t \quad \text{and} \quad \Delta i_t = \beta Y_t + \gamma X_t + \eta_t$$

- Two potential concerns with event-study approach:
  - $\Sigma_\varepsilon > 0$ and $\beta \neq 0 \Rightarrow$ simultaneity bias
  - $\Sigma_X > 0$ and $\gamma \neq 0 \Rightarrow$ omitted variable bias
- Idea: consider two subsamples
  - S_1 : subsample of FOMC-announcement days
  - S_0 : subsample of non FOMC-announcement days

  If $\Sigma^0_\eta < \Sigma^1_\eta$ (variance of η_t is larger in S_1 than in S_0), α is identified from the difference between the covariance matrix of Y_t and Δi_t computed in S_1 and in S_0
- Regression 1: $Y_t = \mathcal{R}^l_t$; Regression 2: $Y_t = \mathcal{T}^l_t - \mathcal{T}^l_{t-1}$

Event study with high-frequency instrumental variable

$$Y_t = a + b\Delta i_t + \varepsilon_t$$

- Event-study concerns:
  - Omitted variable bias
  - Eurodollar futures rate may respond to Y_t on policy days
- Instrument for Δi_t with (unexpected) change in a *narrow 30-minute window* around the FOMC announcement
- For each $t \in S_1$ define $z_t \equiv i_{t,m_t^*+20} - i_{t,m_t^*-10}$
  - $i_{t,m}$: daily 30-day Fed Funds futures rate on minute m of day t
  - m_t^* : minute of day t when FOMC announcement is made
- Estimate b on sample S_1 using z_t as HFIV for Δi_t

Impact of monetary policy on returns and turnover

	E-based		H-based		HFIV	
	Estimate	Std dev	Estimate	Std dev	Estimate	Std dev
Return	-3.77	1.02	-6.18	1.87	-8.57	1.69
Turnover	-.0025	.0007	-.0045	.0017	-.0043	.0009

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On the day of the announcement, a 25 bp increase in policy rate $\Rightarrow$

- stock return declines by .94%, 1.56%, or 2.14%
- turnover rate decline in the range 17% to 30% (e.g., $(.0025/4)/.0037 \approx .17$)

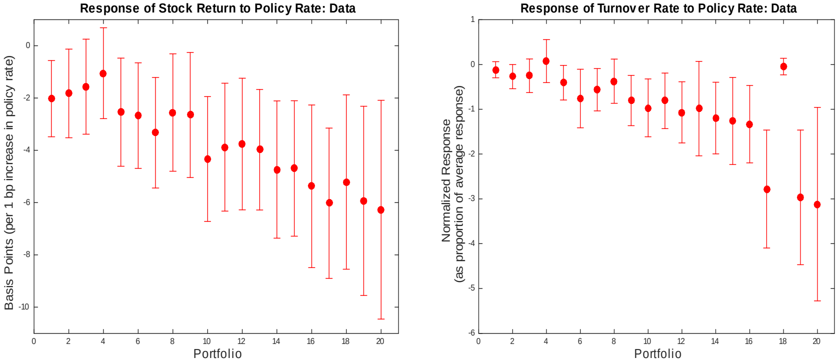
Announcement-day effects across liquidity portfolios

1. For each policy date, t, calculate $\mathcal{T}_t^s$ as the average turnover rate of an individual stock, s, over all trading days during the four weeks prior to the policy date
2. Stocks with $\mathcal{T}_t^s$ between $[5(i-1)]^{\text{th}}$ percentile and $(5i)^{\text{th}}$ percentile are sorted into the i^{th} portfolio, $i = 1, ..., 20$
3. Estimate announcement-day effects for each portfolio

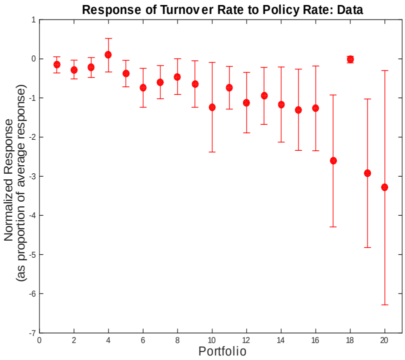
Announcement-day effects across liquidity portfolios

		E-based		H-based		HFIV	
Portfolio	Turnover	Return	Turnover	Return	Turnover	Return	Turnover
1	.11	-2.03***	-.0003	-3.40***	-.0008	-5.80***	-.0008**
2	.19	-1.83**	-.0008**	-3.77***	-.0014**	-5.95***	-.0011**
3	.25	-1.57*	-.0007	-3.02*	-.0012*	-4.54***	-.0014**
4	.31	-1.05	.0002	-2.69	.0005	-4.29***	-.0031***
5	.37	-2.54**	-.0011**	-5.21**	-.0020 **	-5.89***	-.0017***
6	.42	-2.67***	-.0021**	-4.58**	-.0039***	-3.43**	-.0016
7	.47	-3.33***	-.0016**	-6.11**	-.0031***	-6.38***	-.0022***
8	.53	-2.55**	-.0011	-4.81**	-.0024**	-6.14***	-.0024***
9	.58	-2.65**	-.0023***	-5.00**	-.0034**	-8.02***	-.0025***
10	.65	-4.33***	-.0027***	-7.25***	-.0065**	-8.19***	-.0029***
11	.71	-3.88***	-.0023***	-6.20***	-.0039***	-6.63***	-.0036***
12	.78	-3.76***	-.0030***	-5.98***	-.0059***	-8.84***	-.0048***
13	.86	-3.98***	-.0028*	-6.62***	-.0050 ***	-11.15***	-.0036***
14	.95	-4.73***	-.0034***	-7.71***	-.0061**	-9.13***	-.00341*
15	1.06	-4.69***	-.0035***	-7.61***	-.0068**	-9.35***	-.0052***
16	1.19	-5.37***	-.0037***	-9.10***	-.0066**	-12.66***	-.0047***
17	1.36	-6.02***	-.0078***	-10.50***	-.0136 ***	-12.15***	-.0078***
18	1.61	-5.21***	-.0001	-8.82***	-.0001	-13.90***	-.0098***
19	2.02	-5.93***	-.0083***	-10.57***	-.0153***	-13.37***	-.0098***
20	3.11	-6.27***	-.0088***	-12.01***	-.0172**	-15.70***	-.0125***
NYSE	.94	-3.77***	-.0025***	-6.18***	-.0045**	-8.57***	-.0043***

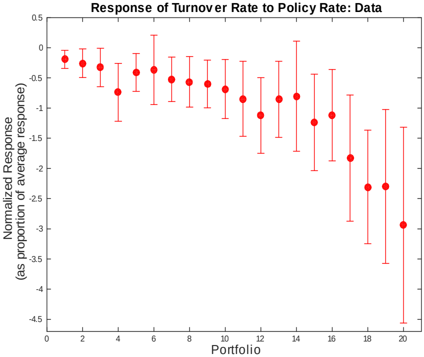
Liquidity portfolios: returns and turnover (E-based)



Liquidity portfolios: returns and turnover (H-based)



Liquidity portfolios: returns and turnover (HFIV)



Announcement-day effects for individual stocks (E-based)

$$\mathcal{R}_t^s = \beta_0 + \beta_1 \Delta i_t + \beta_2 \mathcal{T}_t^s + \beta_3 \overline{\mathcal{T}_t^s} \times \overline{\Delta i_t} + D_s + D_t + \beta_4 (\Delta i_t)^2 + \beta_5 (\mathcal{T}_t^s)^2 + \varepsilon_{st}$$

- Δi_t : announcement-day change in 3-month Eurodollar futures rate
- $\mathcal{T}_t^s$: average turnover rate of individual stock s over all trading days during the four weeks prior to policy date
- $\overline{\mathcal{T}_t^s} \equiv (\mathcal{T}_t^s - \mathcal{T})$ and $\overline{\Delta i_t} \equiv (\Delta i_t - \Delta i)$
- D_s: stock fixed effect; D_t: quarterly time dummy
- ε_{st} : error term for stock s on policy announcement day t
- Theory suggests $\beta_3 < 0$

Announcement-day effects for individual stocks (E-based)

$$\begin{aligned}\mathcal{R}_t^s &= \beta_0 + \beta_1 \Delta i_t + \beta_2 \mathcal{T}_t^s + \beta_3 \overline{\mathcal{T}_t^s} \times \overline{\Delta i_t} \\ &+ D_s + D_t + \beta_4 (\Delta i_t)^2 + \beta_5 (\mathcal{T}_t^s)^2 + \varepsilon_{st}\end{aligned}$$

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Announcement-day effects for individual stocks (E-based)

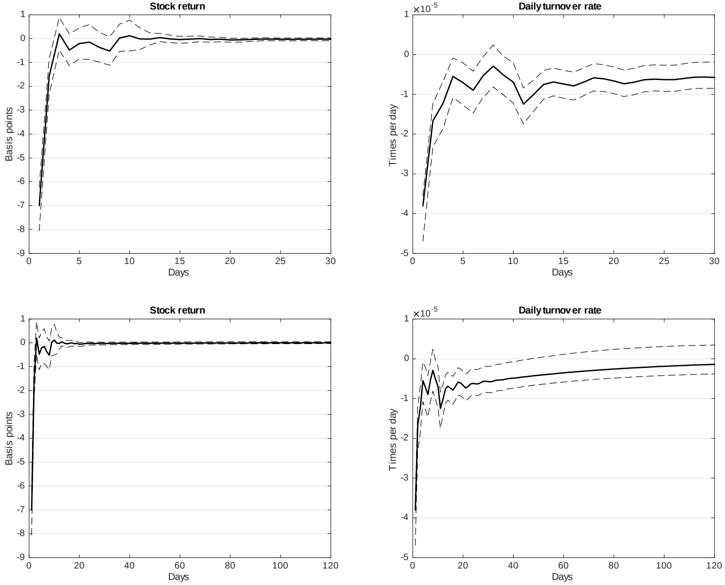
Variable	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)
Δi_t	-2.52	-2.40	-2.46	-2.37	-2.44	-3.36	-3.37	-3.62	-3.63
	(.086)	(.090)	(.091)	(.097)	(.098)	(.099)	(.100)	(.110)	(.110)
$\mathcal{T}_t^s$	25.93	25.36	17.54	22.37	13.93	45.29	42.58	39.09	33.13
	(2.26)	(2.26)	(3.08)	(2.29)	(3.16)	(5.71)	(7.55)	(5.72)	(7.71)
$\overline{\mathcal{T}_t^s} \times \overline{\Delta i_t}$		-109.43	-121.14	-100.43	-111.09	-403.98	-415.17	-398.96	-410.15
		(25.36)	(25.76)	(25.28)	(25.68)	(28.22)	(28.71)	(28.06)	(28.55)
D_s			yes		yes		yes		yes
D_t				yes	yes			yes	yes
$(\Delta i_t)^2$						.947	.947	1.00	1.00
						(.041)	(.042)	(.042)	(.043)
$(\mathcal{T}_t^s)^2$						-1696.88	-1921.29	-1378.21	-1418.23
						(392.48)	(465.31)	(389.33)	(466.21)
R^2	.0084	.0086	.0085	.0314	.0316	.0132	.0132	.0363	.0364

Dynamic responses of aggregate returns and turnover

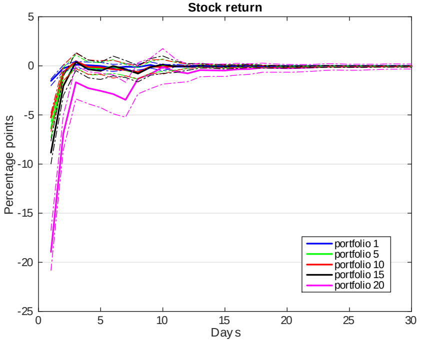
$$Y_t = \sum_{j=1}^{10} B_j Y_{t-j} + u_t$$

- $Y_t = \left(i_t, \mathcal{R}_t^I, \mathcal{T}_t^I\right)'$ for every day in the sample
- i_t : 3-month Eurodollar rate on day t
- $\mathcal{R}_t^I$: average stock-market return on day t
- $\mathcal{T}_t^I$: average stock-market turnover rate on day t
- External high-frequency instrument to identify money shocks

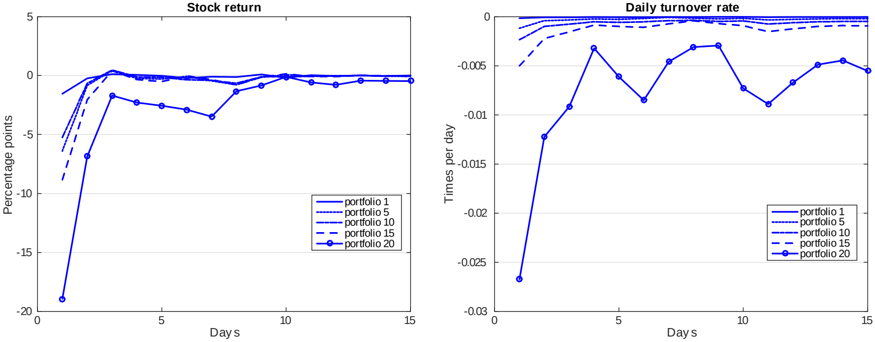
Dynamic responses of aggregate returns and turnover



Liquidity portfolios: dynamic responses



Liquidity portfolios: dynamic responses



Theory: monetary policy shocks and multiple assets

- $\mu_t \sim M$-state Markov chain $[\sigma_{ij}]$ | $A^m_{t+1} = \mu_t A^m_t$
- N asset classes | segmented OTC markets | different α^s
- Investors choose $\left\{a^s_{t+1}, a^{ms}_{t+1}\right\}^N_{s=1}$

Equilibrium conditions

$$\phi_i^s = \bar{\beta}\delta \sum_{j \in \mathbb{M}} \sigma_{ij} \left[\bar{\varepsilon} + \phi_j^s + \alpha^s \theta \int_{\varepsilon_L}^{\varepsilon_j^{s*}} (\varepsilon_j^{s*} - \varepsilon) dG(\varepsilon) \right]$$

$$Z_i = \frac{\bar{\beta}}{\mu_i} \sum_{j \in \mathbb{M}} \sigma_{ij} \left[Z_j + \alpha^s \theta \int_{\varepsilon_j^{s*}}^{\varepsilon_H} (\varepsilon - \varepsilon_j^{s*}) dG(\varepsilon) \frac{Z_j}{\varepsilon_j^{s*} + \phi_j^s} \right]$$

$$Z_i^s = \frac{G\left(\varepsilon_i^{s*}\right) A^s}{1 - G\left(\varepsilon_i^{s*}\right)} \left(\varepsilon_i^{s*} + \phi_i^s\right)$$

$$Z_i = \sum_{s \in \mathbb{N}} Z_i^s$$

Calibration

dividend process	$y_{t+1} = e^{x_{t+1}} y_t$	$\bar{\gamma} = 1 + .04/365$
	$x_{t+1} \sim \mathcal{N}\left(\bar{\gamma} - 1, \Sigma^2\right)$	$\Sigma = .12/\sqrt{365}$
number of asset classes	N	20
asset supply	A^s	1
distribution of asset liquidity	$\{\alpha^s\}_{s=1}^{20}$	estimated
monetary policy shocks	$\{\mu_i\}_{i=1}^{7}, \ [\sigma_{ij}]$	estimated
discount factor	β	$(0.97)^{1/365}$
bargaining power	θ	1
idiosyncratic shocks	ε	$\sim U[0,1]$
asset destruction	δ	$(0.7)^{1/365}$

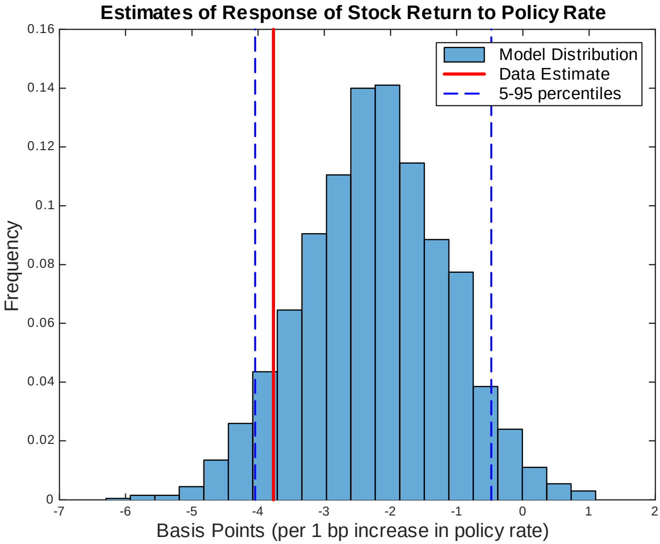
The quantitative exercises

- Compute equilibrium price functions
- Feed into the model the actual path of the policy rate (3-month Eurodollar futures)
- Simulate 1000 dividend samples of equal length as data sample and compute equilibrium path for each sample
- Exercise 1: run aggregate event-study regression on each sample
- Exercise 2: for each asset class, run event-study on each sample
- Exercise 3: estimate VAR impulse responses on each sample (same specification and identification procedure as empirical work)
- For each exercise, report distribution of estimates across simulations

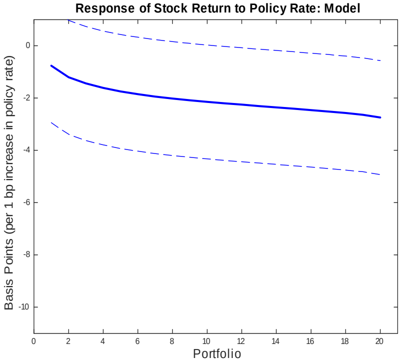
Announcement-day effects on returns and turnover

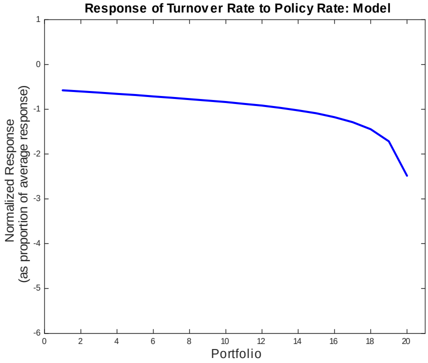
	Model	E-based	H-based	HFIV
Return	-2.23	-3.77	-6.18	-8.57
Turnover	-.0001	-.0025	-.0045	-.0043

Announcement-day effects on returns (E-based)

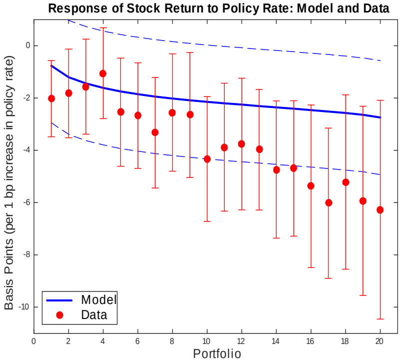


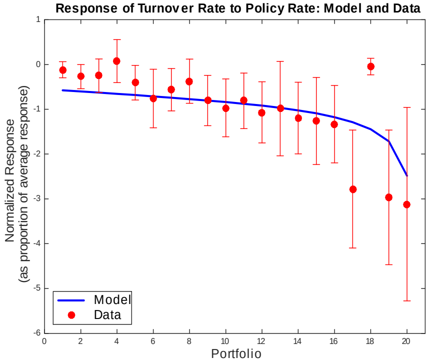
Liquidity portfolios: returns and turnover (E-based)



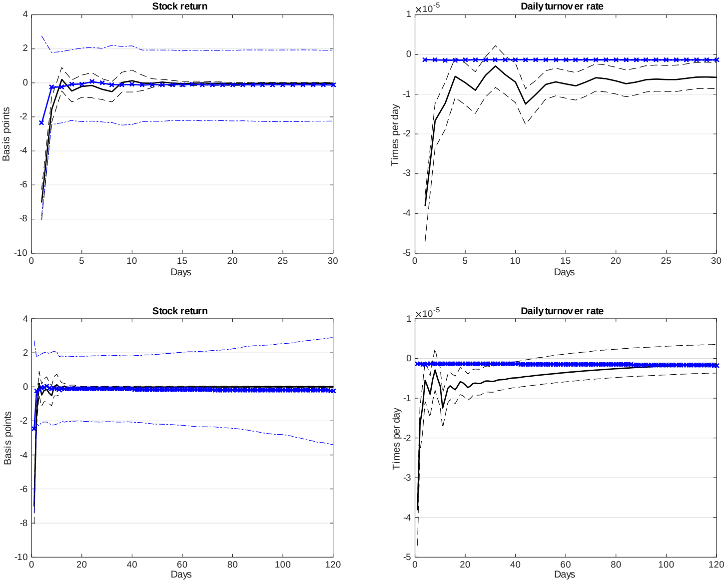


Liquidity portfolios: returns and turnover (E-based)





Dynamic responses of aggregate returns and turnover



Summary

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We documented, modeled, and quantified a new mechanism:

the turnover-liquidity transmission mechanism of monetary policy.

Summary

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These effects are larger for more liquid stocks.

- *What is the mechanism?*

We documented, modeled, and quantified a new mechanism:

the turnover-liquidity transmission mechanism of monetary policy.

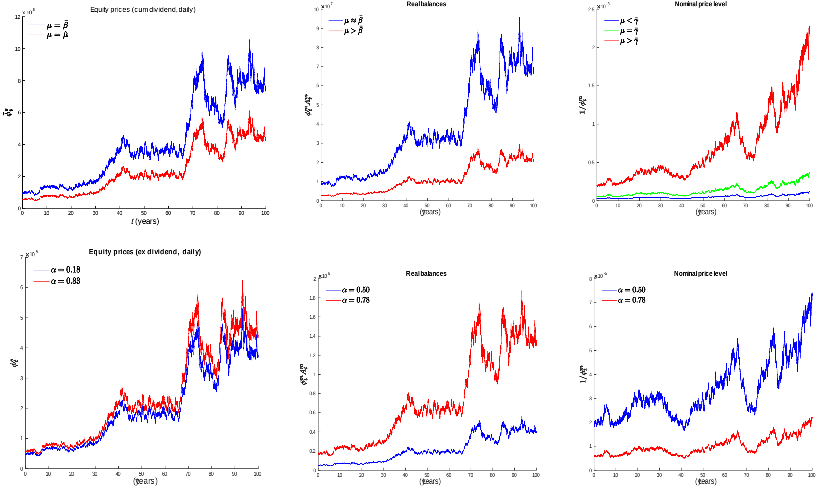
tight money $\Rightarrow$ scarcer means of payment $\Rightarrow$ turnover falls $\Rightarrow$ price falls

To do ...

- Study other assets
- Endogenize α^s
- Incorporate leverage (realistic, likely to improve model fit)

end.

Monetary policy, OTC frictions, and asset prices



VAR identification with high-frequency external instrument

$$\begin{aligned} KY_t &= \textstyle\sum_{j=1}^{J} C_j Y_{t-j} + \varepsilon_t && \text{(SVAR)} \\ Y_t &= \textstyle\sum_{j=1}^{J} \left(K^{-1} C_j\right) Y_{t-j} + u_t && \text{(VAR)} \\ u_t &= K^{-1} \varepsilon_t && \text{(RFR)} \\ E\left(u_t u_t'\right) &= K^{-1} K^{-1\prime} && \text{(IC1)} \end{aligned}$$

- K, C_j: $n \times n$ matrices
- $\varepsilon_t \in R^n$, $E(\varepsilon_t) = 0$, $E(\varepsilon_t \varepsilon_t') = I$, $E(\varepsilon_t \varepsilon_s') = 0$ for $s \neq t$
- The identification problem:
  - want to find n^2 elements of K^{-1}
  - condition (IC1) provides $n(n+1)/2$ independent conditions
  - need $n(n-1)/2$ additional conditions

VAR identification with high-frequency external instrument

$$Y_t = \left(i_t, \mathcal{R}_t^I, \mathcal{T}_t^I\right)', \ \varepsilon_t = \left(\varepsilon_t^i, \varepsilon_t^{\mathcal{R}}, \varepsilon_t^{\mathcal{T}}\right)', \ u_t = \left(u_t^i, u_t^{\mathcal{R}}, u_t^{\mathcal{T}}\right)'$$

$$u_t = K^{-1}\varepsilon_t \tag{RFR}$$

$$K^{-1} = \begin{bmatrix} k_i^i & k_i^{\mathcal{R}} & k_i^{\mathcal{T}} \\ k_{\mathcal{R}}^i & k_{\mathcal{R}}^{\mathcal{R}} & k_{\mathcal{R}}^{\mathcal{T}} \\ k_{\mathcal{T}}^i & k_{\mathcal{T}}^{\mathcal{R}} & k_{\mathcal{T}}^{\mathcal{T}} \end{bmatrix}$$

$$\Rightarrow$$

$$\begin{bmatrix} u_t^i \\ u_t^{\mathcal{R}} \\ u_t^{\mathcal{T}} \end{bmatrix} = \begin{bmatrix} k_i^i \\ k_{\mathcal{R}}^i \\ k_{\mathcal{T}}^i \end{bmatrix} \varepsilon_t^i + \begin{bmatrix} k_i^{\mathcal{R}} \\ k_{\mathcal{R}}^{\mathcal{R}} \\ k_{\mathcal{T}}^{\mathcal{R}} \end{bmatrix} \varepsilon_t^{\mathcal{R}} + \begin{bmatrix} k_i^{\mathcal{T}} \\ k_{\mathcal{R}}^{\mathcal{T}} \\ k_{\mathcal{T}}^{\mathcal{T}} \end{bmatrix} \varepsilon_t^{\mathcal{T}}$$

VAR identification with high-frequency external instrument

Find instrument z_t for ε_t^i, i.e.,

$$\begin{aligned} \mathbb{E}(z_t \varepsilon_t^{\mathcal{R}}) &= \mathbb{E}(z_t \varepsilon_t^{\mathcal{T}}) = 0 < \mathbb{E}(z_t \varepsilon_t^i) \equiv v \text{ for all } t \\ &\Rightarrow \\ \Lambda &\equiv \mathbb{E}(z_t u_t) = K^{-1}\mathbb{E}(z_t \varepsilon_t) = \left(k_i^i, k_{\mathcal{R}}^i, k_{\mathcal{T}}^i\right)' v \end{aligned}$$

Since $\Lambda = (\Lambda_1, \Lambda_2, \Lambda_3)'$ is a known (3×1) vector,

$$\left.\begin{aligned} vk_i^i &= \Lambda_1 \\ vk_{\mathcal{R}}^i &= \Lambda_2 \\ vk_{\mathcal{T}}^i &= \Lambda_3 \end{aligned}\right\} \Rightarrow \frac{k_{\mathcal{R}}^i}{k_i^i} = \frac{\Lambda_2}{\Lambda_1} \text{ and } \frac{k_{\mathcal{T}}^i}{k_i^i} = \frac{\Lambda_3}{\Lambda_1}$$

- $\frac{\Lambda_2}{\Lambda_1} = \frac{\mathbb{E}(z_t u_t^{\mathcal{R}})}{\mathbb{E}(z_t u_t^i)}$: slope of regression of $u_t^{\mathcal{R}}$ on u_t^i proxied with z_t
- $\frac{\Lambda_3}{\Lambda_1} = \frac{\mathbb{E}(z_t u_t^{\mathcal{T}})}{\mathbb{E}(z_t u_t^i)}$: slope of regression of $u_t^{\mathcal{T}}$ on u_t^i proxied with z_t
- Our instrument: $z_t = i_{t,m_t^*+20} - i_{t,m_t^*-10}$ (on subsmaple S_1)

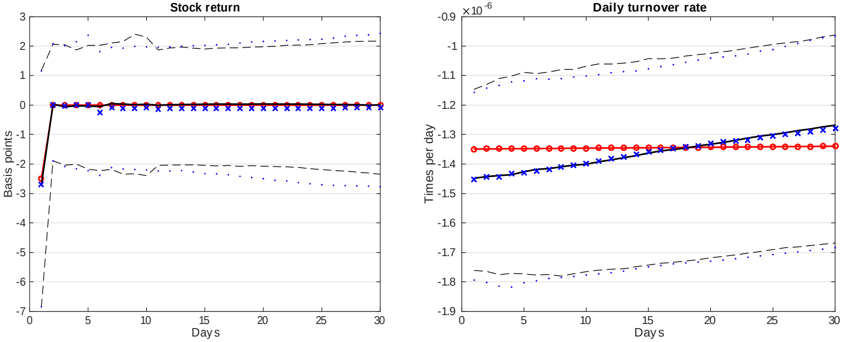
VAR: choice of number of lags

- Akaike information criterion: 10 lags
- Schwarz's Bayesian information criterion: 5 lags
- Hannan and Quinn information criterion: 5 lags
- Check how well these specifications estimate the true theoretical impulse responses (simulations of length equal to data sample)

VAR: choice of number of lags

- Compute equilibrium functions for calibrated model
- Set policy rate to follow the AR(1) process estimated from data
- Compute true theoretical IR to a 1bp increase in the policy rate
- Simulate 1000 samples of the dividend and the policy rate
- For each sample:
  - compute equilibrium paths for $\left\{\mathcal{R}_t^l\right\}$ and $\left\{\mathcal{T}_t^l\right\}$
  - estimate baseline VAR with 5 and 10 lags. Compute IR to 1bp increase in policy rate (with HFIV identification scheme)
- For version with 5 and 10 lags, report median IR and 95% confidence intervals (from distribution of estimates). Compare with true theoretical IR

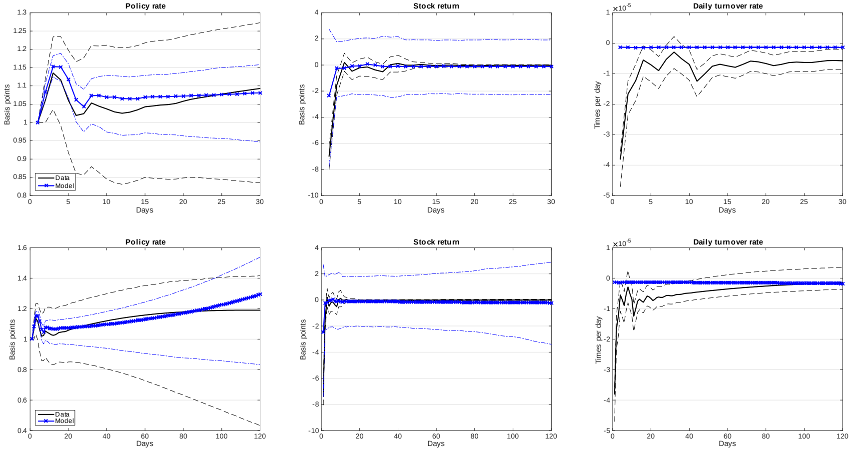
VAR: choice of number of lags



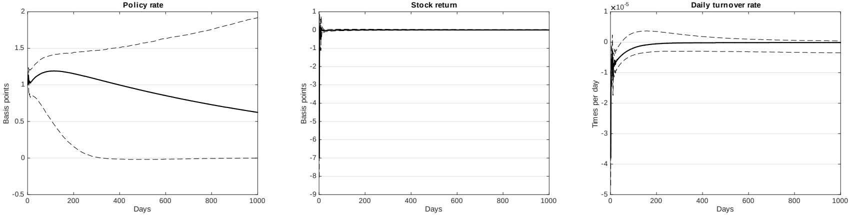
VAR: confidence intervals for impulse responses

- *Recursive wild bootstrap* to compute 95% confidence intervals for estimated IR coefficients (Gonçalves and Kilian, 2004)
- Given VAR estimates, $\{\hat{B}_j\}_{j=1}^{J}$ and $\{\hat{u}_t\}$, generate bootstrap draws, $\{Y_t^b\}$, by $Y_t^b = \sum_{j=1}^{J} \hat{B}_j Y_{t-j} + e_t^b \hat{u}_t$
- e_t^b : the realization of a scalar random variable taking values of -1 or 1, each with probability $1/2$
- HFIV identification procedure requires bootstrap draws for proxy variable, $\{z_t^b\}$. Generate random draws for the proxy variable via $z_t^b = e_t^b z_t$ (Mertens and Ravn, 2013)
- Use the bootstrap samples $\{Y_t^b\}$ and $\{z_t^b\}$ to reestimate the VAR coefficients and compute the associated impulse responses. The confidence intervals are the percentile intervals of the distribution of 10,000 bootstrap estimates for the impulse response coefficients

Impulse responses to a 1pp increase in the policy rate



Impulse responses to 1pp increase in policy rate (data)



Results for portfolios sorted on liquidity betas

$$\mathcal{R}_t^s = \alpha^s + \beta_0^s \mathcal{T}_t^l + \beta_1^s MKT_t + \beta_2^s HML_t + \beta_3^s SMB_t + \varepsilon_t^s$$

- For each stock s, run it 73 times, once for each policy day t_k, using sample of all trading days between day t_{k-1} and day t_k
- 292 betas estimated for each stock s, i.e., $\left\{\left\{\beta_j^s(k)\right\}_{j=0}^{3}\right\}_{k=1}^{73}$, where $\beta_j^s(k)$ is for sample $(t_{k-1}, t_k]$
- For each policy day t_k, stocks with $\beta_0^s(k)$ between $[5(i-1)]^{\text{th}}$ percentile and $(5i)^{\text{th}}$ percentile are sorted into the i^{th} portfolio, $i = 1, ..., 20$
- Compute daily $\mathcal{R}_t^i$ and $\mathcal{T}_t^i - \mathcal{T}_{t-1}^i$ for each portfolio
- Run event-study regressions portfolio-by-portfolio

Results for portfolios sorted on liquidity betas

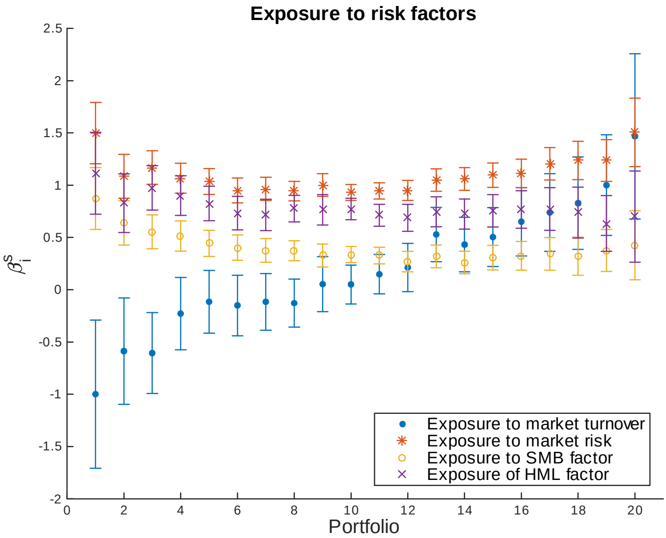
	Return		Turnover	
Portfolio	Estimate	Std dev	Estimate	Std dev
1	-.85	1.89	-.0033	.0021
2	-2.11	1.41	-.0052***	.0019
3	-1.22	1.23	-.0052***	.0013
4	-3.38***	1.19	-.0048***	.0015
5	-2.69**	1.20	-.0036**	.0014
6	-2.68**	1.10	-.0040***	.0013
7	-2.64***	.99	-.0032**	.0014
8	-2.39**	1.06	-.0037***	.0014
9	-3.59***	1.02	-.0028*	.0015
10	-3.17***	1.03	-.0028*	.0013
11	-3.92***	1.09	-.0053***	.0016
12	-4.71***	1.05	-.0006	.0015
13	-4.41***	1.17	-.0034**	.0013
14	-6.12***	1.28	-.0025*	.0014
15	-6.53***	1.43	-.0047***	.0014
16	-6.63***	1.50	-.0032*	.0017
17	-7.25***	1.57	-.0044***	.0015
18	-6.66***	1.78	-.0055***	.0017
19	-10.16***	2.42	-.0080***	.0019
20	-13.17***	3.02	-.0082***	.0023

Liquidity-beta portfolios: exposure to Fama-French risk factors

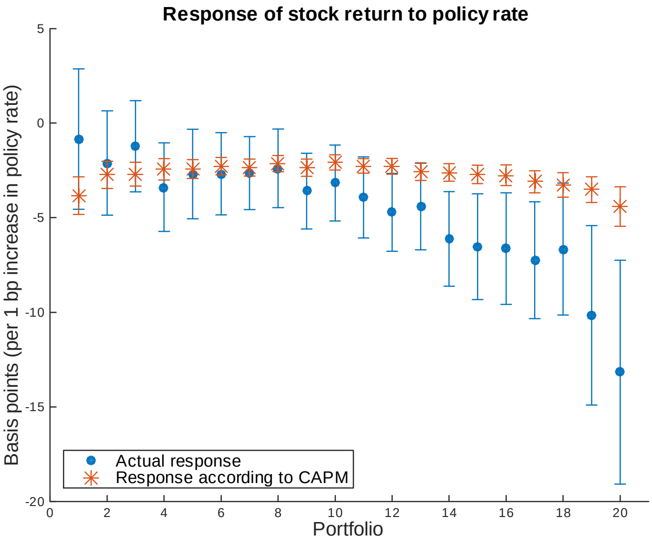
$$\mathcal{R}_t^s = \alpha^s + \beta_0^s \mathcal{T}_t^l + \beta_1^s MKT_t + \beta_2^s HML_t + \beta_3^s SMB_t + \varepsilon_t^s$$

- Construct the series of *monthly* return for each of the 20 portfolios for 1994-2001, $\{(\mathcal{R}_t^i)_{i=1}^{20}\}$
- Run above regression to estimate $\{\{\beta_j^i\}_{i=1}^{20}\}_{j=0}^{3}$
- For each factor j, plot $(i, \beta_j^i)_{i=1}^{20}$ (normalize $\{\beta_0^i\}_{i=1}^{20}$ by dividing it by $|\beta_0^1|$)

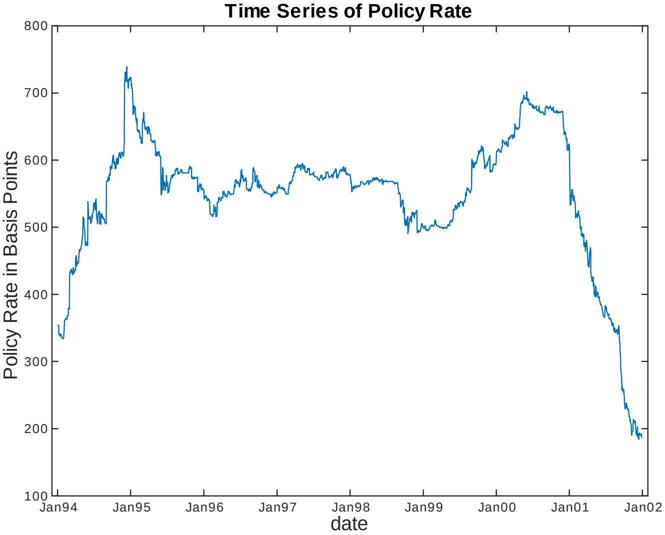
Liquidity-beta portfolios: exposure to Fama-French risk factors



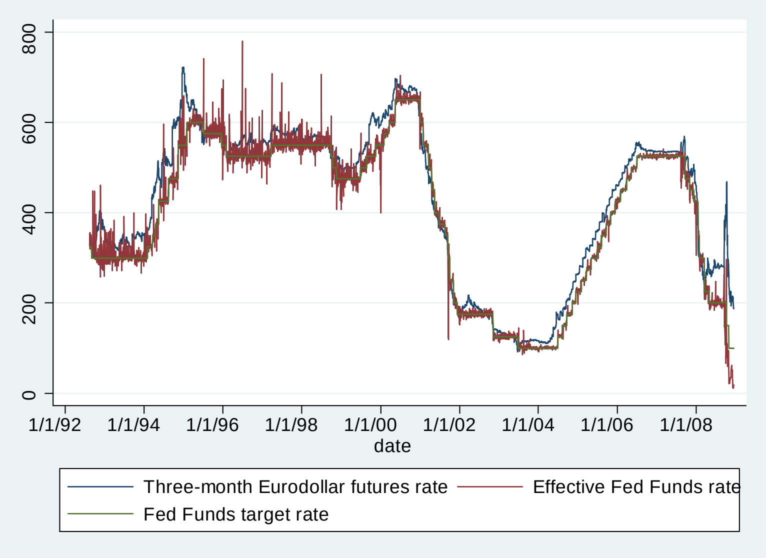
Response of returns: simple CAPM vs. liquidity-beta portfolios



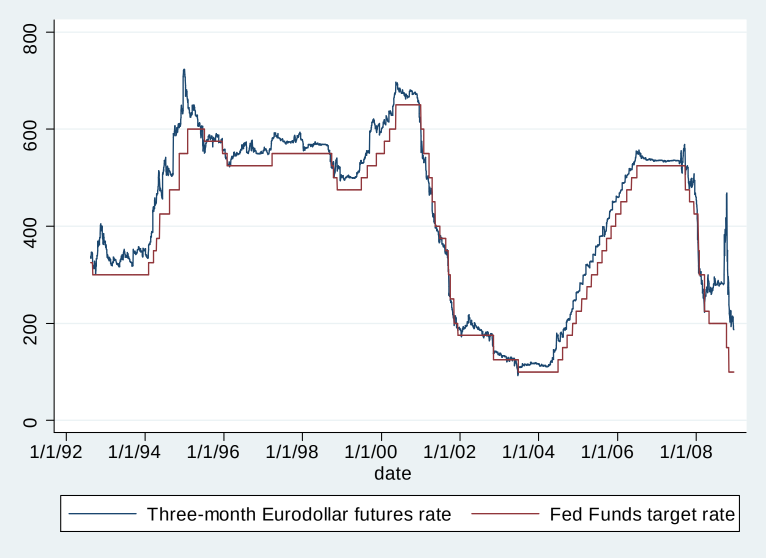
3-month Eurodollar futures rate



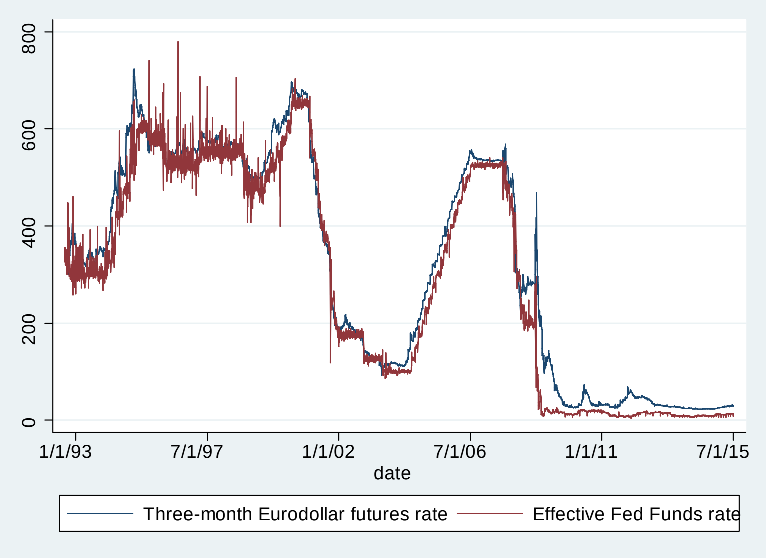
Rates: 3-month Eurodollar, effective Fed Funds, target



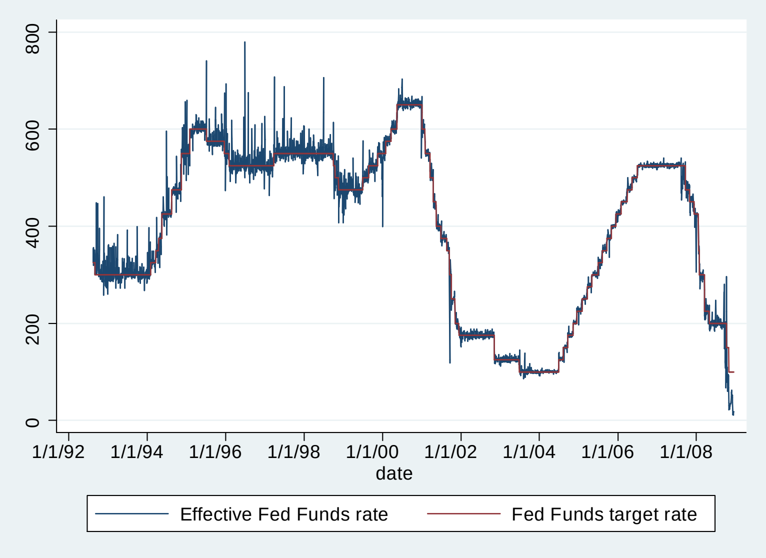
Rates: 3-month Eurodollar futures, Fed Funds target



Rates: 3-month Eurodollar futures, effective Fed Funds



Rates: effective Fed Funds, Fed Funds target



Estimated monetary policy process

- i_t: 3-month Eurodollar futures rate on day t (in bps)
- Estimate (1994-2001): $\ln i_t = (1-\xi)\ln i_0 + \xi \ln i_{t-1} + \varepsilon_t$

$$\mathbb{E}(i_t) = 346 \text{ bps} \qquad SD(i_t) = 172 \text{ bps} \qquad \xi = .9997652$$

- Approximate AR(1) with 7-state Markov chain, $\{r_i, \sigma_{ij}\}_{i,j=1}^{7}$ (Rouwenhorst method, Galindev and Lkhagvasuren, 2010)
- Mapping between $\{r_i, \sigma_{ij}\}_{i,j=1}^{7}$ and $\{\mu_i, \sigma_{ij}\}_{i,j=1}^{7}$ given by

$$r_i \approx \frac{\mu_i - \bar{\beta}}{\bar{\beta}}$$

Announcement effects for liquidity portfolios: 1994-2007

		E-based		H-based		HFIV	
Portfolio	Turnover	Return	Turnover	Return	Turnover	Return	Turnover
1	.18	-3.85***	-.0004	-9.75***	-.0015**	-6.25***	-.0009***
2	.35	-4.26***	-.0006	-12.13***	-.0017	-6.84***	-.0012**
3	.45	-3.60***	-.0008	-9.46***	-.0015	-5.69***	-.0022**
4	.54	-3.22***	-.0002	-11.40***	-.0012	-5.49***	-.0029***
5	.62	-4.83***	-.0010	-14.28***	-.0025	-7.23***	-.0019
6	.69	-3.65***	-.0009	-12.79***	-.0009	-5.16***	-.0018
7	.76	-4.88***	-.0008	-15.21***	-.0014	-7.33***	-.0029*
8	.84	-4.34***	-.0011	-21.28***	-.0019	-7.244***	-.0026**
9	.91	-5.10***	-.0013	-14.78***	-.0009	-8.79***	-.0030*
10	.97	-5.60***	-.0016	-16.57***	-.0040	-9.08***	-.0036*
11	1.06	-5.12***	-.0016	-14.48***	-.0025	-8.02***	-.0034
12	1.15	-5.73***	-.0022*	-17.27***	-.0047	-9.46***	-.0049***
13	1.26	-6.87***	-.0020	-18.10***	-.0038	-11.40***	-.0042***
14	1.37	-5.95***	-.0026	-18.36***	-.0026	-9.84***	-.0049**
15	1.49	-6.48***	-.0039**	-18.97***	-.0080*	-10.00***	-.0059***
16	1.66	-7.60***	-.0035*	-22.26***	-.0050	-13.25***	-.0069***
17	1.85	-7.46***	-.0035***	-21.64***	-.0042	-13.03***	-.0093***
18	2.13	-8.35***	-.0041*	-23.26***	-.0076	-14.31***	-.0096***
19	2.57	-8.33***	-.0061**	-23.74***	-.0115	-13.85***	-.0123***
20	3.63	-9.28***	-.0062	-27.55***	-.0061	-16.40***	-.0189***
NYSE	1.23	-5.73***	-.0022*	-16.79***	-.0037	-9.43***	-.0053**