Liquidity Creation as Volatility Risk

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Liquidity and Volatility

1. Liquidity creation is a key service provided by the financial sector
   - makes it cheaper to pledge/transfer income streams from assets
   - enables risk sharing and information aggregation
   - underlies banking and market making
2. Volatility is a central feature of financial markets
   - important for asset prices, cost of capital
   - fluctuates widely over time
   - very large premium for hedging volatility shocks (variance premium)
3. Volatility and liquidity are known to move together
   - financial crises: volatility spikes and triggers a liquidity crunch (Brunnermeier, 2009)
   - Nagel (2012): higher VIX predicts higher returns to liquidity creation (stock reversals)

This paper

We show theoretically and empirically that:

1. Liquidity creation has a built-in negative exposure to volatility risk
   - when volatility rises $\rightarrow$ liquidity providers lose
   - fundamental, due only to information asymmetry
   - no capital constraints or other financial frictions, liquidity providers are fully diversified
2. Returns to liquidity creation reflect compensation for its volatility risk exposure
   - we show this using stock reversals
   - reversal portfolios have large negative volatility β's
   - expected reversal return = volatility β $\times$ variance premium
   - when volatility risk increases $\rightarrow$ expected reversal return rises

$\Rightarrow$ A new, asset-pricing perspective on the risks and returns to financial intermediation

Intuition

1. Liquidity providers trade against informed and uninformed traders
   - informed traders: buy if price will rise, sell if price will fall
   - to liquidity providers, their payoff looks like a straddle (call + put)

$\Rightarrow$ Liquidity providers are short a set of straddles
   - a positive shock to volatility $\rightarrow$ straddles increase in value $\rightarrow$ liquidity providers lose

   $\Rightarrow$ liquidity providers have a negative exposure to volatility shocks

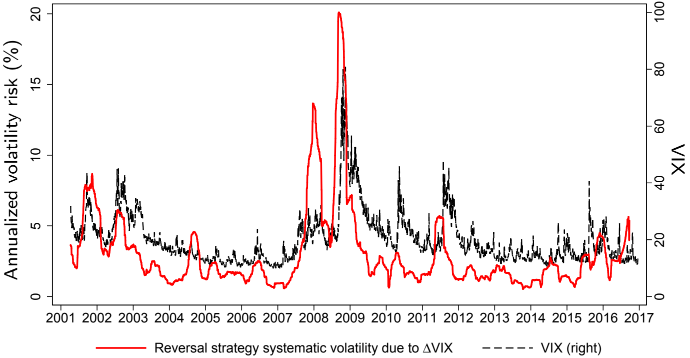
2. Volatility is highly correlated across assets, and with market volatility

   $\Rightarrow$ liquidity providers' volatility exposure is undiversifiable, systematic
   - systematic volatility risk carries a big premium (variance premium)

$\Rightarrow$ Liquidity providers charge the variance premium for their volatility risk exposure
   - when volatility is higher, so is volatility risk $\rightarrow$ liquidity providers charge a higher premium

Volatility risk exposure of stock reversals

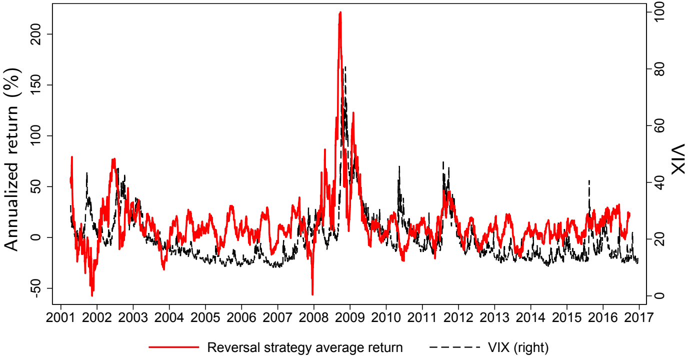
1. Use stock reversals as proxy for returns to liquidity creation
   - sort large-cap stocks into deciles by day's normalized return
   - buy lowest-return decile, sell highest-return decile, hold for five days
2. Reversal strategy's daily $\beta_{\Delta VIX} = -19$ bps (per 1 point ΔVIX)
   - big relative to 27 bps average five-day return
   - plot rolling estimate of volatility risk: $\sigma\left(\beta_{\Delta VIX} \times \Delta VIX\right)$



$\Rightarrow$ When VIX is higher $\rightarrow$ reversal strategy has higher volatility risk

Volatility risk and the average return of stock reversals

1. Following Nagel (2012), plot the rolling average reversal strategy return against VIX



2. Reversal strategy return is strongly increasing in VIX

$\Rightarrow$ Higher VIX $\rightarrow$ reversal has higher volatility risk $\rightarrow$ higher return

Roadmap

1. Overview ✓
2. Related literature
3. Model
4. Empirical results

Related literature

1. Volatility risk: Engle (1982); Andersen, Bollerslev, Diebold and Labys (2003); Carr and Wu (2008); Bollerslev, Tauchen and Zhou (2009); Drechsler and Yaron (2010); Todorov (2010); Drechsler (2013)

2. Liquidity and asymmetric information: Akerlof (1970); Grossman and Stiglitz (1980); Kyle (1985); Glosten and Milgrom (1985); Gorton and Pennacchi (1990)

3. Macro finance and liquidity: Gromb and Vayanos (2002); Eisfeldt (2004); Brunnermeier and Pedersen (2009); Adrian and Shin (2010); Moreira and Savov (2017); Drechsler, Savov, Schnabl (2018)

4. Asset prices and liquidity: Amihud and Mendelson (1986); Lehman (1990); Amihud (2002); Pástor and Stambaugh (2003); Acharya and Pedersen (2005); Nagel (2012)

Model

1. Kyle (1985) framework with stochastic volatility
   - three time periods: 0, $t \in (0,1)$, and 1
   - three agents: informed trader, liquidity-demanders, liquidity providers
   - N assets: traded at time 0, pay off at time 1:

$$p_{i,1} = \overline{v}_i + \sigma_{i,1} v_i$$

   - $v_i \sim N(0,1)$ is idiosyncratic; informed already knows v_i at $t = 0$
   - $\sigma_{i,1}$ is uncertain to everyone, value realized at time 1:

$$\sigma_{i,1} = k_{i,m}\sigma_{m,1} + \varepsilon_{\sigma_i}$$

   - $k_{i,m} > 0$ is loading on market vol $\sigma_{m,1}$, captures strong commonality
   - time t: news arrives about $\sigma_{i,1}$

2. Liquidity-demanders: demand $z_i \sim N\left(0, \sigma_{z_i}^2\right)$

3. Informed trader: demands y_i to maximize expected time-1 profit

$$\max_{y_i} \; E_0^Q \left[y_i \left(p_{i,1} - p_{i,0}\right) \middle| \, v_i \right]$$

   - values profits under economy's risk-neutral measure Q

Equilibrium pricing

1. Liquidity providers absorb order flow $X_i = y_i + z_i \rightarrow$ hold $-X_i$ shares. Set $p_{i,t}$ to break even under Q measure $\Rightarrow$ no financial frictions

$$p_{i,t} \;=\; E_t^Q\left[p_{i,1} \middle| X_i\right] \;=\; \overline{v}_i + X_i \frac{E_t^Q\left[\sigma_{i,1}\right]}{2\sigma_{z_i}}$$

   - $p_{i,0}$ moves in direction of order flow X_i
   - higher $E_t^Q[\sigma_{i,1}] \rightarrow$ informed has more info $\rightarrow p_{i,t}$ more sensitive to X_i

2. Let $\Delta p_{i,0} = (p_{i,0} - \overline{v}_i)$ denote the time-0 price change. Then:

$$-X_i = -\Delta p_{i,0} \frac{2\sigma_{z_i}}{E_0^Q\left[\sigma_{i,1}\right]}$$

$\Rightarrow$ liquidity providers hold a portfolio of reversals: they buy assets that go down and short assets that go up, in proportion to $-\Delta p_{i,0}$

   - we proxy for their portfolio by constructing reversal portfolios

Volatility risk exposure

1. When **volatility news** arrives at t, the price change is:

$$\Delta p_{i,t} \;=\; \frac{X_i}{2\sigma_{z_i}}\left(E_t^Q\left[\sigma_{i,1}\right] - E_0^Q\left[\sigma_{i,1}\right]\right)$$

   $\Rightarrow$ a volatility increase drives $p_{i,t}$ further in direction of X_i $\rightarrow$ reversals lose on both sides as longs go down and shorts go up

2. Market vol betas β_{i,σ_m} of liquidity providers' holdings $-X_i \Delta p_{i,t}$ are *negative*:

$$\beta_{i,\sigma_m} \;=\; -\frac{X_i^2}{2\sigma_{z_i}} k_{i,m} < 0$$

$\Rightarrow$ Liquidity providers have *undiversifiable* volatility risk even though assets' time-1 payoffs are totally *idiosyncratic*

- correlation in assets' second moments induces undiversifiable risk in liquidity providers' returns
- contrasts with inventory models, where increase in idio vol is priced because liquidity providers not diversified (Stoll 1978, Nagel 2012)

Predictions

1. **Exposure**: Liquidity providers have negative exposure to market vol

$$\beta_{\sigma_m} = \left(\sum_{i=1}^{N} \beta_{i,\sigma_m} \right) < 0$$

2. **Risk premium**: Liquidity providers earn a large, positive risk premium (liquidity premium) from time 0 to 1

$$E_0^P \left[\sum_{i=1}^{N} -X_i \Delta p_{i,1} \right] = \beta_{\sigma_m} \underbrace{\left(E_0^P \left[\sigma_{m,1} \right] - E_0^Q \left[\sigma_{m,1} \right] \right)}_{\text{variance premium } \ll 0} > 0$$

   - large variance premium: VIX $\gg$ realized vol of S&P 500

3. **Predictability**: cross section and time series
   - cross-section: more negative β_{σ_m} $\rightarrow$ bigger average return
   - time series: higher VIX $\rightarrow$ higher vol risk $\rightarrow$ larger variance premium $\rightarrow$ higher average reversal returns

Data and empirical strategy

1. Each day, sort stocks into deciles by return (normalized by rolling standard deviation) and into quintiles by size
   - drop penny stocks and earnings announcements (public news events)
   - focus on period since decimilization: 4/9/2001 to 12/31/2016 (3,958 days), when liquidity provision became competitive
   - hold portfolios for one to five days as in Nagel, 2012 $\rightarrow$ *not* HFT
   - reversal strategies: buy low-return deciles, sell high-return deciles: 10–1 ("Lo–Hi"), 9–2, . . . , 5–6

Average returns and CAPM alphas

$$R^p_{t,t+5} \;=\; \alpha^p + \sum_{s=1}^{5} \beta^p_s R^M_{t+s} + \epsilon^p_{t,t+5}$$

	5-day average return (%)				
	Lo–Hi	2–9	3–8	4–7	5–6
Small	1.16	0.56	0.21	0.05	0.04
2	0.65	0.30	0.17	0.03	−0.03
3	0.35	0.24	0.01	0.11	−0.01
4	0.22	0.23	0.13	0.06	0.01
Big	0.27	0.25	0.18	0.11	0.05

	5-day CAPM alpha (%)				
	Lo–Hi	2–9	3–8	4–7	5–6
Small	1.14	0.55	0.20	0.04	0.04
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Big	0.25	0.24	0.18	0.11	0.05

1. Large-cap reversal strategy has an average five-day return of 27 bps (13.6% annual), Sharpe ratio 0.59
   - small-stock reversals are larger but Sharpe ratio is similar
   - CAPM alphas ≈ average returns ⇒ CAPM cannot price the reversals

Volatility risk exposure

$$R^p_{t,t+5} = \alpha_p + \sum_{s=1}^{5} \beta_s^{p,VIX} \Delta VIX_{t+s} + \epsilon^p_{t,t+5}$$

	5-day ΔVIX beta				
	Lo–Hi	2–9	3–8	4–7	5–6
Small	−0.81	−0.49	−0.57	−0.26	−0.31
2	−0.82	−0.34	−0.24	−0.31	0.03
3	−0.57	−0.26	−0.36	−0.32	−0.01
4	−0.54	−0.26	−0.18	0.01	−0.04
Big	−0.64	−0.34	−0.09	−0.01	−0.01

	5-day ΔVIX beta *t*-statistic				
	Lo–Hi	2–9	3–8	4–7	5–6
Small	−2.66	−3.29	−3.02	−1.31	−1.78
2	−3.47	−2.21	−1.82	−2.39	0.25
3	−3.63	−2.52	−3.82	−4.16	−0.09
4	−4.30	−2.78	−2.70	0.13	−0.93
Big	−4.28	−3.09	−1.34	−0.25	−0.31

1. Reversal strategy has a large negative beta to ΔVIX
   - large-cap reversal drops by 64 bps per 5-point VIX increase (1.3 standard deviations); big relative to average return (27 bps)

Volatility risk exposure, controlling for R^M

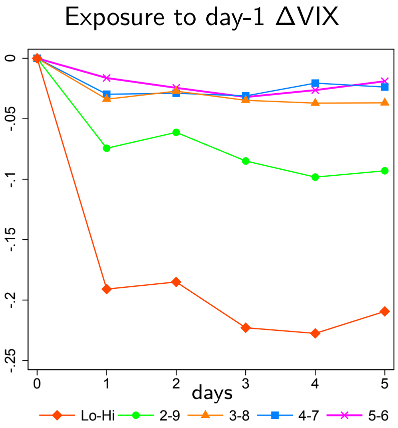
$$R^p_{t,t+5} = \alpha_p + \sum_{s=1}^{5} \beta_s^{p,VIX} \Delta VIX_{t+s} + \sum_{s=1}^{5} \beta_s^{p,M} R^M_{t+s} + \epsilon^p_{t,t+5}$$

	5-day ΔVIX beta				
	Lo–Hi	2–9	3–8	4–7	5–6
Small	−0.75	−0.60	−0.80	−0.13	−0.46
2	−0.65	−0.44	−0.35	−0.04	−0.08
3	−0.62	−0.12	−0.25	−0.14	−0.14
4	−0.33	−0.30	−0.34	0.04	−0.01
Big	−0.71	−0.37	−0.18	0.05	−0.13

	5-day ΔVIX beta *t*-statistic				
	Lo–Hi	2–9	3–8	4–7	5–6
Small	−1.53	−2.40	−2.43	−0.43	−1.75
2	−1.87	−1.75	−1.78	−0.20	−0.47
3	−2.23	−0.72	−1.71	−0.85	−1.26
4	−1.41	−2.28	−3.00	0.48	−0.13
Big	−3.33	−2.42	−1.46	0.62	−1.62

2. Reversal strategy's ΔVIX beta is unaffected by controlling for R^M

Volatility risk exposure persistence



1. Impact of ΔVIX shock is highly persistent, as predicted by model
   - goes against other explanations (e.g. fire sales by liquidity providers due to a tightening VaR constraint)

Predictability regressions

1. Model: higher VIX $\rightarrow$ higher volatility risk $\rightarrow$ higher reversal return

$$R^p_{t,t+5} \;=\; \alpha^p + \beta^p VIX_t + \epsilon^p_{t,t+5}$$

	5-day VIX loading ($\times 10^2$)				
	Lo–Hi	2–9	3–8	4–7	5–6
Small	3.53	3.48	3.51	2.72	0.16
2	7.01	3.14	2.68	1.40	−0.27
3	4.84	2.98	1.16	0.93	−0.10
4	2.94	2.33	1.52	−0.04	0.44
Big	5.37	3.69	1.74	0.67	0.08

	5-day R^2 (%)				
	Lo–Hi	2–9	3–8	4–7	5–6
Small	0.09	0.19	0.26	0.16	0.00
2	0.95	0.37	0.35	0.11	0.00
3	0.72	0.70	0.15	0.08	0.00
4	0.46	0.71	0.42	0.00	0.05
Big	2.18	2.11	0.77	0.15	0.00

2. *VIX* predicts reversal strategy returns
   - extends result of Nagel (2012) to cross section
   - very high R^2 for large stocks given five-day horizon

Fama-Macbeth regressions

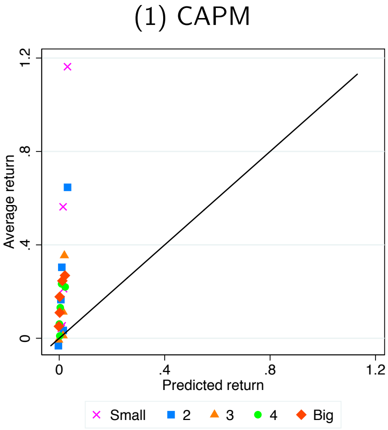
	Factor premia					
	Market	t-stat.	Δ VIX	t-stat.	R.m.s.	p-value
(1)	0.03	2.06			0.18	0.00
(2)	0.05	3.04	-0.49	-8.57	0.14	0.00

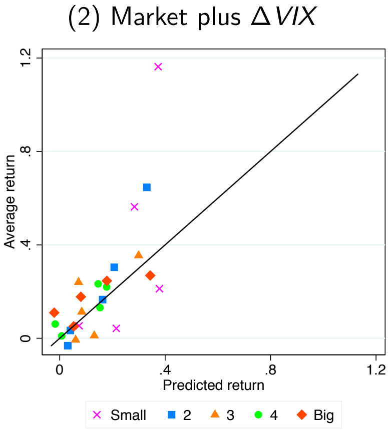
	(1) CAPM pricing error				
	Lo-Hi	2–9	3–8	4–7	5–6
Small	1.13	0.55	0.20	0.04	0.03
2	0.61	0.29	0.16	0.02	-0.03
3	0.33	0.23	-0.00	0.10	-0.00
4	0.20	0.22	0.13	0.06	0.01
Big	0.25	0.23	0.18	0.11	0.05

	(2) Market plus ΔVIX pricing error				
	Lo-Hi	2–9	3–8	4–7	5–6
Small	0.79	0.28	-0.17	-0.02	-0.17
2	0.32	0.10	0.00	-0.01	-0.06
3	0.06	0.17	-0.12	0.03	-0.07
4	0.04	0.09	-0.02	0.08	0.00
Big	-0.07	0.07	0.10	0.13	-0.00

1. ΔVIX factor explains the reversal strategy returns of large- and mid-cap stocks. Large and significant premium

Fama-Macbeth regressions





1. ΔVIX factor explains the reversal strategy returns of large- and mid-cap stocks. Large and significant premium

Is the implied price of volatility risk consistent with other markets?

1. Volatility risk is traded directly in option markets
   - VIX is the price of a basket of options that replicates the realized variance of the S&P 500 over next 30 days
   - However, ΔVIX is not a return because basket changes daily
2. We replicate the VIX using S&P 500 options (99.83% accuracy) and use the change in the price of a given basket to get a VIX return
   - to get closer to the relevant horizon for liquidity providers, use VIXN, the near-term component of VIX ($\approx$ 22 days) $\rightarrow$ VIXN return
3. Average daily VIX return is -1.54%, VIXN return is -2.01%
   - in line with variance premium literature (e.g. Carr and Wu, 2008; Bollerslev, Tauchen, and Zhou, 2009, Drechsler and Yaron 2010)

Option-implied prices of volatility risk

1. Model: liquidity providers exposed to shocks to *expected* variance
   - expected variance captured by ΔVIX and $\Delta VIXN$

   $\Rightarrow$ use R^{VIX} and R^{VIXN} to restrict price of risk of ΔVIX and $\Delta VIXN$

	R^{VIX}	R^{VIXN}
ΔVIX	6.938*** (0.106)	
ΔVIXN		5.696*** (0.120)
Constant	−1.511*** (0.184)	−1.986*** (0.264)
Obs.	3,788	3,787
R^2	0.529	0.372

1. Implied price of risk: -22 bps for ΔVIX and -35 bps for $\Delta VIXN$

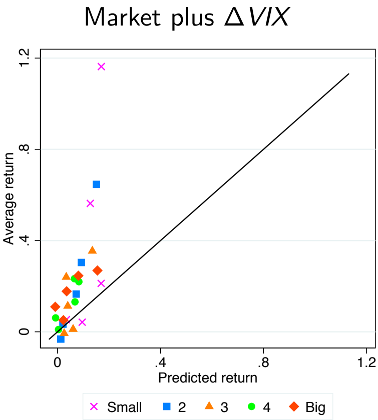
Pricing regressions with an options-based price of risk

	Pricing error using VIX return				
	Lo-Hi	2–9	3–8	4–7	5–6
Small	0.99	0.44	0.04	0.02	−0.05
2	0.50	0.21	0.09	0.01	−0.04
3	0.22	0.21	−0.05	0.07	−0.03
4	0.14	0.17	0.06	0.07	0.01
Big	0.11	0.16	0.14	0.12	0.03

	Pricing error using VIXN return				
	Lo-Hi	2–9	3–8	4–7	5–6
Small	0.87	0.34	0.04	−0.04	−0.09
2	0.42	0.16	0.07	−0.00	−0.05
3	0.12	0.12	−0.08	0.04	−0.03
4	0.05	0.10	0.01	0.07	−0.01
Big	0.01	0.13	0.11	0.11	0.03

1. Near-term volatility risk priced the same in reversals and options
   - the options-based price of ΔVIX explains most of the reversal return for large stocks (pricing error falls from 25 bps to 11 bps)
   - the near-term $\Delta VIXN$ fully explains it (pricing error is just 1 bp)

Pricing regressions with an options-based price of risk



1. Options-based price of $\Delta VIXN$ explains reversal returns of large- and mid-cap stocks

$\Rightarrow$ Returns to liquidity provision reflect broad economic risks (as opposed to financial frictions/segmented markets)

Takeaways

1. Liquidity creation is a key service of the financial sector
2. Exposure to asymmetric information $\Rightarrow$ exposure to volatility risk
   - liquidity providers implicitly short straddles
3. Volatility risk carries a large premium
   - explains the level and variation of liquidity premium
4. A new, asset-pricing perspective on the risks and returns to financial intermediation

APPENDIX

Reversal portfolio summary statistics

	Market cap (billions)				
	Lo-Hi	2-9	3-8	4-7	5-6
Small	0.05	0.05	0.05	0.05	0.05
2	0.16	0.16	0.17	0.17	0.17
3	0.43	0.44	0.44	0.44	0.44
4	1.35	1.37	1.37	1.37	1.37
Big	49.57	54.15	56.02	56.02	55.40

	Amihud illiquidity ($\times 10^6$)				
	Lo-Hi	2-9	3-8	4-7	5-6
Small	33.60	21.08	14.42	10.34	8.58
2	5.73	3.98	2.79	2.07	1.70
3	1.36	1.00	0.71	0.52	0.43
4	0.30	0.22	0.16	0.11	0.09
Big	0.03	0.02	0.01	0.01	0.01

1. Large-cap portfolios $\approx$ 96.4% of market value
   - liquid, low transaction costs

Reversal portfolio summary statistics

	Sorting-day returns (%)				
	Lo-Hi	2-9	3-8	4-7	5-6
Small	−24.36	−6.92	−4.21	−2.34	−0.74
2	−17.54	−6.05	−3.73	−2.07	−0.64
3	−14.77	−5.43	−3.34	−1.87	−0.60
4	−11.97	−4.70	−2.92	−1.64	−0.52
Big	−7.45	−3.43	−2.13	−1.18	−0.38

	Share turnover (%)				
	Lo-Hi	2-9	3-8	4-7	5-6
Small	10.28	7.37	6.71	6.28	6.07
2	7.84	4.45	3.85	3.60	3.42
3	6.41	3.11	2.63	2.46	2.36
4	5.59	2.76	2.44	2.25	2.21
Big	3.28	2.13	1.99	1.89	1.83

2. Reversal strategy has large negative sorting-day return (by construction)
   - larger for small stocks because sorting is by normalized return
   - reversal associated with high share turnover, demand for liquidity

Average returns and CAPM alphas

$$R^p_{t,t+5} = \alpha^p + \sum_{s=1}^{5} \beta^p_s R^M_{t+s} + \epsilon^p_{t,t+5}$$

	5-day average return (%)				
	Lo–Hi	2–9	3–8	4–7	5–6
Small	1.16	0.56	0.21	0.05	0.04
2	0.65	0.30	0.17	0.03	−0.03
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4	0.22	0.23	0.13	0.06	0.01
Big	0.27	0.25	0.18	0.11	0.05

	5-day standard deviation (%)				
	Lo–Hi	2–9	3–8	4–7	5–6
Small	10.54	7.11	6.19	5.99	5.89
2	6.44	4.59	4.03	3.82	3.74
3	5.11	3.18	2.71	3.02	2.28
4	3.88	2.47	2.10	1.92	1.77
Big	3.25	2.28	1.78	1.55	1.31

	5-day CAPM alpha (%)				
	Lo–Hi	2–9	3–8	4–7	5–6
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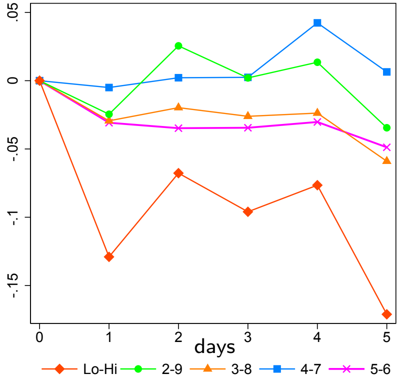
4	0.20	0.23	0.13	0.06	0.01
Big	0.25	0.24	0.18	0.11	0.05

	5-day CAPM alpha *t*-statistic				
	Lo–Hi	2–9	3–8	4–7	5–6
Small	6.57	4.88	1.97	0.44	0.39
2	5.83	3.96	2.43	0.33	−0.50
3	3.85	4.31	−0.03	2.25	−0.14
4	3.13	5.54	3.82	2.00	0.31
Big	4.51	6.48	6.24	4.35	2.50

1. Large-stock reversal strategy has an average annual return of 13.6% ($= 0.27\% \times 252/5$), volatility 23%, Sharpe ratio 0.59
   - small-stock reversal returns are larger but more volatile
   - CAPM alphas $\approx$ average returns $\Rightarrow$ CAPM cannot price reversals

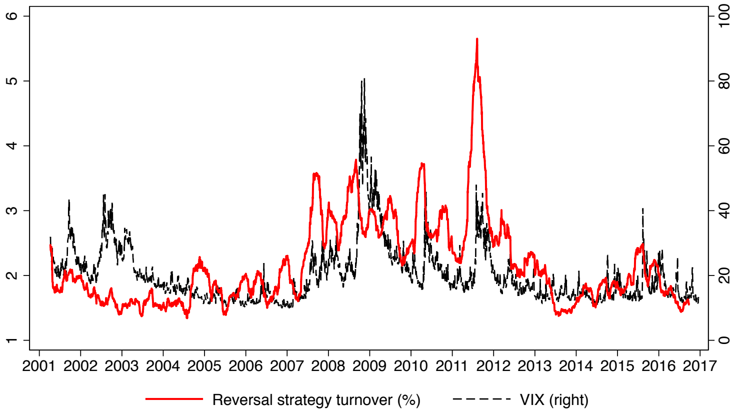
Volatility risk exposure persistence, controlling for R^M

Exposure to day-1 ΔVIX, controlling for R^M



1. Impact of ΔVIX shock is persistent, as predicted by model
   - goes against view that liquidity providers are offloading inventory due to a tightening VaR constraint (impact would be transitory)

Reversal strategy turnover



1. Reversal strategy turnover increasing in VIX
   - higher quantity and premium ⇒ shift in liquidity demand curve
   - goes against financial constraints theories, which work through shifts in supply curve (e.g., VaR constraint)