Empirical Asset Pricing

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Limits of Arbitrage

Lecture Outline

1. Examples of arbitrage
2. Limits of arbitrage: the theory
3. Empirical evidence on limits of arbitrage
4. Intermediary Asset Pricing

Relevant readings:

- Mitchell, Pulvino, and Stafford (2002, JF)
- Gromb and Vayanos , 2010, Limits of arbitrage: the state of the theory
- Take a look at: DeLong, Shleifer, Summers, Waldman (DSSW, JPE 1990), Shleifer and Vishny (JF 1997), Gromb and Vayanos (2002), Abreu and Brunnermeier (JFE 2002), Abreu and Brunnermeier (Econometrica, 2003), Brunnermeier and Pedersen (RFS 2009)

- Brunnermeier and Nagel (JF 2004), Ben-David, Franzoni, Moussawi (RFS 2012), Coval and Stafford (JFE 2007), Di Maggio, Franzoni, Kogan, Xing (forthcoming, JF)

- Intermediary Asset Pricing: He, Kelly, Manela (JFE, 2017), Adrian, Etula, Muir (JF, 2014), Haddad and Muir (2025)

1. Example of An Arbitrage Opportunity

The Palm-3Com Anomaly

- In **March 2000**, 3Com **carved out** 5% of its stake in Palm via an IPO and announced it would spin off the remaining 95% stake before year-end, distributing **1.525 shares of Palm per share of 3Com**

- Investors could therefore buy Palm *directly* or *indirectly* by buying the shares embedded within 3Com

- After the IPO: **Palm traded at \$95.06**, **3Com at \$81.81**

- **The law of one price was violated:**

$$\$81.81 < 1.525 \times \$95.06 = \$145$$

- Given that 3Com had zero debt, this market pricing implied that the remaining assets of 3Com were assigned a **negative value** by the market (**negative stub value**)

- Why were investors willing to buy one share of Palm at \$95.06 when they could acquire it for $\$\frac{81.81}{1.525} = \$53.65$ via a 3Com share?

- **Likely cause:** positive sentiment for dot-com stocks

- However, **limits of arbitrage** are needed to explain why rational investors did not arbitrage the mispricing away

- **Arbitrageurs** could: buy 3Com shares, short-sell Palm shares, and wait for the distribution to cover the short position

- **Short-selling costs** prevented this trade: there were very few Palm shares available for lending and shorting fees were **extremely high (30% annually)**

- **Uncertainty about the spin-off date** made the arbitrage position risky to hold

- **Mitchell, Pulvino, and Stafford (2002, JF)** study 82 negative stub value situations (1985–2000) and assess systematically which limits to arbitrage prevent convergence
  - **Fundamental risk**: mispricing may never converge (bankruptcy, third-party acquisition, delisting); occurs in $\sim$30% of cases
  - **Horizon risk**: time to convergence is highly variable (average 236 days, range 1–2796); strategy often underperforms while the position is open, deterring capital commitment

- **Margin risk**: marking-to-market of the long-short position can trigger margin calls, forcing premature liquidation at a loss
- **Shorting costs and buy-ins**: short-selling fees can be extreme (Palm rebate rate: -30% annually); buy-ins – where the lender recalls shares – affect $\sim$15% of positions
- **Imperfect information** (their main finding): even after 16 years the strategy's abnormal returns remain statistically weak, meaning that arbitrageurs face deep uncertainty about its profitability; **this limits capital commitment more than any other friction**

2. Limits of arbitrage: the theory

A simple model of limits to arbitrage

- Based on Gromb and Vayanos (2010)

- Two periods: 1 and 2; two assets with **correlated payoffs**: A and B; risk-free rate exogenously set to 0

- **Arbitrageurs** are risk averse with CARA utility (risk aversion α); they trade at time 1 and receive dividends at time 2

- Normally distributed random dividends: d_A and d_B, with mean $\bar{d}_i$ and variance σ_i; assets in **zero net supply**

- Asset B's price is exogenously set to the expected dividend: $p_B = \bar{d}_B$

- There are exogenous **demand (liquidity) shocks** u in asset A; arbitrageurs take the opposite side

- **Equilibrium price of asset A:**

$$p_A = \bar{d}_A + \alpha\sigma_A^2 \left(1 - \rho^2\right) u \tag{1}$$

where ρ is the correlation between the dividends of the two assets

- **Key implications of equation (1):**
  - Demand shocks u affect the price: **arbitrageurs require a risk premium**
  - Assets with **more risk** ($\sigma_A \uparrow$) and **more imperfect substitutes** ($\rho \downarrow$) are **more exposed to demand shocks** (harder to hedge)
  - Higher risk aversion ($\alpha \uparrow$) amplifies the price impact
  - If $\rho = 1$: a **perfect substitute** exists, arbitrage is riskless, and price equals fundamentals. Otherwise, **arbitrage is risky**
- What do we learn? **As long as arbitrageurs have limited risk bearing capacity, and there are no perfect substitutes, demand shocks have price impact** (see Greenwood, 2005)
  - This channel justifies **downward sloping demand curves**

Fundamental vs. Non-Fundamental Risk

- Next, we see that **arbitrageurs' short horizon exacerbates the impact of non-fundamental shocks (i.e., demand shocks)**

- Assume a period 0 in which trading occurs; at time 0, even the expectations of dividends ($\bar{d}_i$) are random with volatility σ_i, and the demand shock u at time 1 is unknown

- Arbitrageurs who must liquidate at time 1 (**short horizon**) bear **two sources of risk** at time 0:
  1. **Fundamental risk**: uncertainty about $\bar{d}_A$ and $\bar{d}_B$
  2. **Non-fundamental risk**: uncertainty about demand shocks u occurring at $t = 1$

- Short-horizon arbitrageurs may therefore refrain from trading against time-0 demand shocks because of non-fundamental risk occurring at $t = 1$

- As a result, the volatility of p_A at time $t = 1$, from the point of view of $t = 0$ is

$$\sigma_0\left(p_{A,1}\right) = \sigma_A\left[1 + \alpha^2\sigma_A^2\left(1 - \rho^2\right)^2\sigma_u^2\right]^{1/2} \tag{2}$$

and the correlation between p_A and p_B is

$$\rho_0\left(p_{A,1}, p_{B,1}\right) = \frac{\rho}{\left[1+\alpha^2\sigma_A^2\left(1-\rho^2\right)^2\sigma_u^2\right]^{1/2}} \tag{3}$$

- **Result:** volatility in (2) exceeds σ_A; correlation in (3) falls below ρ. Demand shocks therefore **increase volatility** and **reduce co-movement** between assets

- **Implication**: **arbitrageurs require a higher premium and prices diverge further from fundamentals** at $t = 0$

  – Non-fundamental risk constrains arbitrageurs' aggressiveness

- If investors had a **long horizon** (hold until $t = 2$), non-fundamental demand at $t = 1$ would have *no* impact on $t = 0$ prices

- **DSSW (1990)** generate divergence from fundamentals in a model with two **identical** ($\rho = 1$) assets where the Law of One Price should hold, but with **autocorrelated** demand shocks for one asset. Crucial assumptions: arbitrageurs with *finite horizons* and an *infinite-horizon economy*. They call this: **noise trader risk**

- Short horizons can be endogenized as **financial constraints** (e.g. Shleifer and Vishny 1997)

- **Bottom line**: non-fundamental risk affects asset prices whenever arbitrageurs have short horizons, even when perfect hedges ($\rho = 1$) exist

Short-selling costs

- In case of positive demand shocks, arbitrageurs want to **short** the asset
- Short-selling is costly: arbitrageurs must post cash as collateral, and the interest earned on that collateral (the **rebate rate**) falls *below* the market interest rate

$$\textbf{rebate rate} = \textbf{market rate} - \textbf{short-selling fee}$$

- Model the short-selling cost as c. The equilibrium price of asset A at time 1 becomes:

$$\begin{aligned} p_A &= \bar{d}_A + \alpha\sigma_A^2\left(1-\rho^2\right)u \quad \text{if } u \leq 0 \\ p_A &= \bar{d}_A + \alpha\sigma_A^2\left(1-\rho^2\right)u + c \quad \text{if } u > 0 \end{aligned}$$

- When $u > 0$, arbitrageurs short asset A, and the price must rise by c to compensate them for the shorting cost
- **Key result:** two assets with *identical* payoffs ($\rho = 1$) subject to demand shocks can trade at *different prices* if short-selling is costly:

$$\begin{aligned} p_A &= \bar{d}_A + c \\ p_B &= \bar{d}_A \end{aligned}$$

- **This directly explains the Palm-3Com anomaly**: Palm received excess demand from sentiment traders and was prohibitively expensive to short

Wealth Effects

- The ability to correct deviations from fundamentals requires **capital**
- In the previous model, arbitrageurs' wealth does not appear because CARA utility implies *constant* absolute risk aversion
- With more general utility (e.g. logarithmic utility in Xiong 2001 and Kyle and Xiong 2001), **wealth increases risk-bearing capacity**: as wealth falls, risk aversion rises effectively
- So, as **wealth decreases**, arbitrageurs are less willing to absorb liquidity shocks and **price correction is smaller** (liquidity dries up)
- This channel is called **wealth effects**
- **Empirical evidence**: Comerton-Forde, Hendershott, Jones, Moulton, and Seasholes (JF, 2010) on NYSE specialists
  - Specialists **withdraw from liquidity provision when they lose money**, consistent with wealth effects
  - Note: **specialists rely on their own capital**, so the channel here is **wealth effects rather than external financial constraints**

Leverage constraints

- Wealth can enter the model through **financial constraints** on arbitrageurs' ability to invest more than their own capital
- One version: **limits on leverage** (margin constraints), as in Gromb and Vayanos 2002 and Brunnermeier and Pedersen 2009
- **Buying on margin**: investor borrows from broker and posts the security as collateral; the security is discounted by a **haircut**, so 100% of its value cannot be borrowed. Similarly, in fixed income: **repo transactions** with haircuts
- The margin requirement is *larger* the *riskier* the security, since the broker wants protection against adverse price moves
- To **short sell**: arbitrageur must post cash in excess of short proceeds (protection against upward price moves); requires **equity capital**
- When there are demand shocks, arbitrageurs want to take the other side – but if their **capital is insufficient**, they cannot short sell enough to enforce the law of one price
- **Bottom line**: when the leverage constraint binds, arbitrage is imperfect

Amplification

- Suppose arbitrageurs enter period 1 with wealth invested in period 0
- A **negative demand shock** lowers the value of assets in their portfolio, making the **leverage constraint binding**
- Arbitrageurs receive **margin calls** from their brokers and are forced to **liquidate**
- Their *sales reinforce* the negative demand shock: arbitrageurs become **consumers** of liquidity rather than providers
- **Amplification:** a feedback loop where losses $\rightarrow$ margin calls $\rightarrow$ fire sales $\rightarrow$ further price declines

Contagion

- In a **multi-asset setting**, a demand shock to one asset may force **liquidation of other securities** in the portfolio
- Two mechanisms:
  - Arbitrageurs may choose to liquidate the **most liquid** securities first (to minimize market impact)
  - Or liquidate the **most volatile** securities that impose higher capital charges (**flight to quality**)
- Either way: a shock to one security **propagates to other securities** through leverage constraints
- Propagation to correlated assets can also arise from **hedging**: risk-averse investors hedge demand for one asset with demand for a correlated asset (Greenwood, 2005, JFE)

Funding Liquidity and Market Liquidity

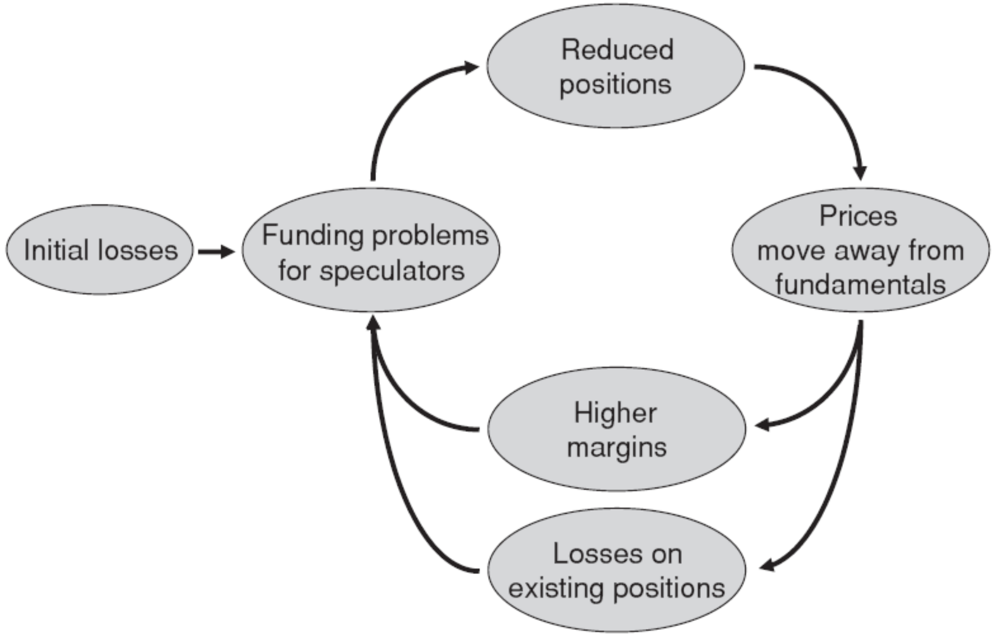
- Brunnermeier and Pedersen (2009) use leverage constraints in a multi-asset setting to generate **amplification** and **contagion** (similar concepts in Gromb and Vayanos, 2002, JFE)

- Two key concepts:

  - **Funding liquidity**: availability of capital for arbitrageurs, which depends on their portfolio performance

  - **Market liquidity**: proximity of security prices to fundamentals following demand shocks

- The two forms of liquidity **reinforce each other** through **loss spirals** and **liquidity spirals**: losses $\rightarrow$ forced liquidations $\rightarrow$ further price pressure $\rightarrow$ larger losses



- The paper also predicts **flights to quality**: after negative shocks, arbitrageurs sell **high-volatility** stocks and buy **low-volatility** stocks to reduce collateral requirements; this *reinforces* the initial shock, since conditional volatility depends positively on past returns (GARCH)

Constraints on Equity Capital

- Operate similarly to leverage constraints: **limited capital** $\Rightarrow$ **limited arbitrage** $\Rightarrow$ **prices diverge from fundamentals**
- Arise naturally when arbitrageurs manage **other people's money**
- **Shleifer and Vishny (1997)**: mutual/hedge fund investors **redeem capital after losses**, precisely when the arbitrage trade is most attractive
- This constrains arbitrageurs' ability to correct mispricing, triggers **liquidations** and **amplification**
- S&V show that these constraints limit liquidity provision not only when they *are* binding, but also when there is merely a *chance* they will bind in the future: **precautionary deleveraging**
- That is, arbitrageurs **fear** future losses will force liquidations, so they *preemptively* limit their exposure to risky assets. Also see Di Maggio et al. (forthcoming) in these notes
- **Risk management** emerges as a response to capital constraints
- Leverage and equity constraints are exogenous in these models, but can be micro-founded on **imperfect information** about manager skill (e.g. Berk and Green, 2004)

Synchronization Risk

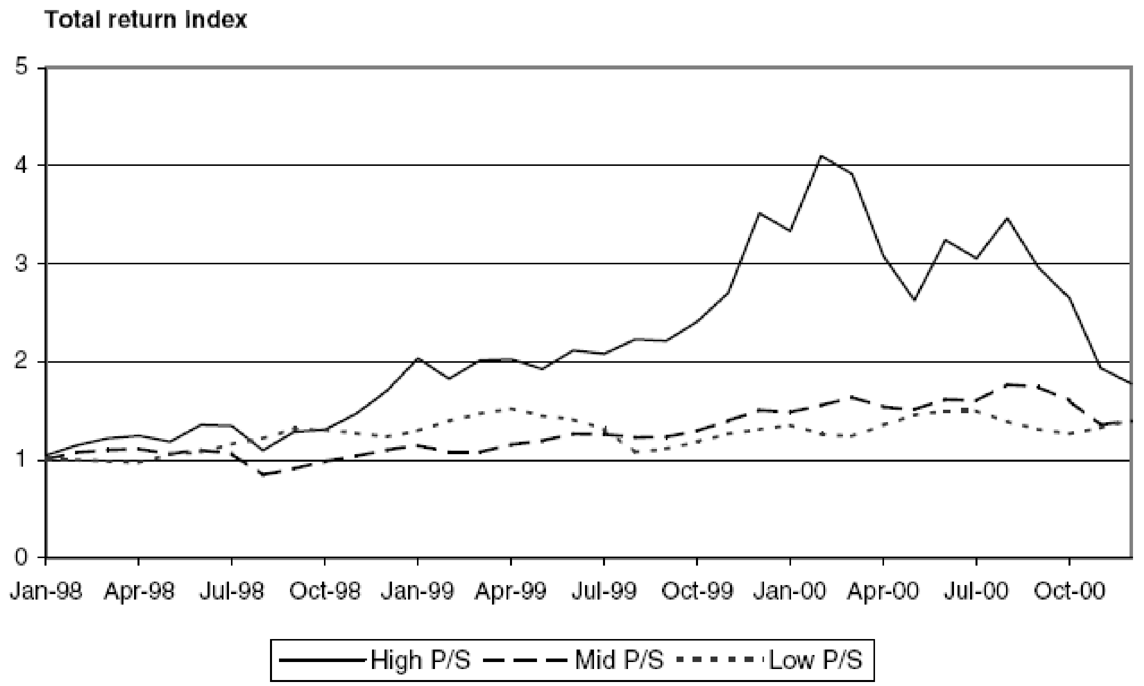
- Abreu and Brunnermeier (2002): arbitrageurs have **limited capital**, so a *single* arbitrageur cannot correct mispricing alone
- Arbitrageurs are **not simultaneously aware** of profit opportunities — they do not necessarily coordinate their entry
- There are **holding costs** (e.g. short-selling fees): it is costly to maintain open positions while waiting for mispricing to correct
- Result: mispricing can **persist** because arbitrageurs fail to coordinate (**synchronization risk**)
- Abreu and Brunnermeier (2003): given these frictions, it can be *rational* for arbitrageurs to **ride the bubble** — trade *in the direction* of mispricing — in anticipation that it will continue for some time before correcting
- Kondor (JF, 2009): similar mechanism. Arbitrageurs decide *when* to enter; they may hold back capital to deploy later if the arbitrage opportunity widens further, generating **persistent price divergence**

3. Empirical Evidence on Limits of Arbitrage

Brunnermeier and Nagel (JF, 2004)

- Technology stocks on Nasdaq rose to **unprecedented levels** during the two years leading up to March 2000

- Implied valuations required either **earnings growth rates** exceeding any previously observed level, or **very low discount rates** — both implausible



- High **price-to-sales (P/S)** stocks (mostly high-tech) experienced a **four-fold price increase** followed by a severe correction after March 2000

- Widely interpreted as a canonical **asset price bubble**

Research Question

- These valuations seem a manifestation of **investor irrationality** — but irrational mispricing cannot survive without **limits to arbitrage**

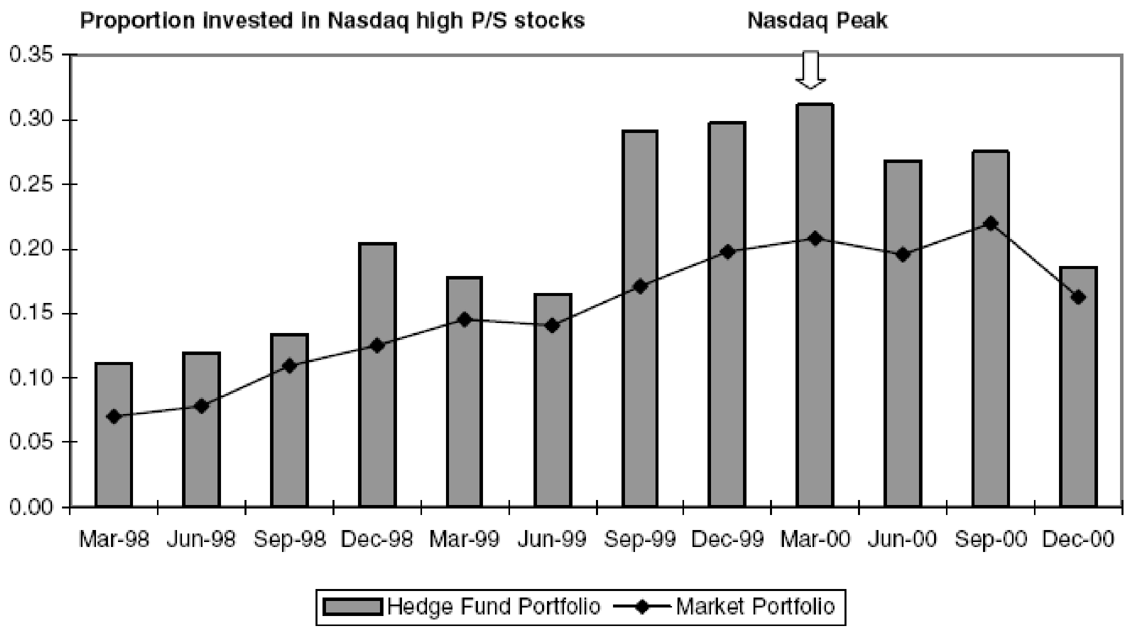
- **Research question**: what were sophisticated arbitrageurs doing during this period? Did they **attack** or **ride** the bubble?

- They focus on **hedge funds** (HFs) as the most sophisticated investor class

- **Data**: 13F filings — all institutions with > $100M in U.S. equity must report end-of-quarter *long* positions
  - **Limitation**: no data on short positions

The weights of HFs in the tech sector

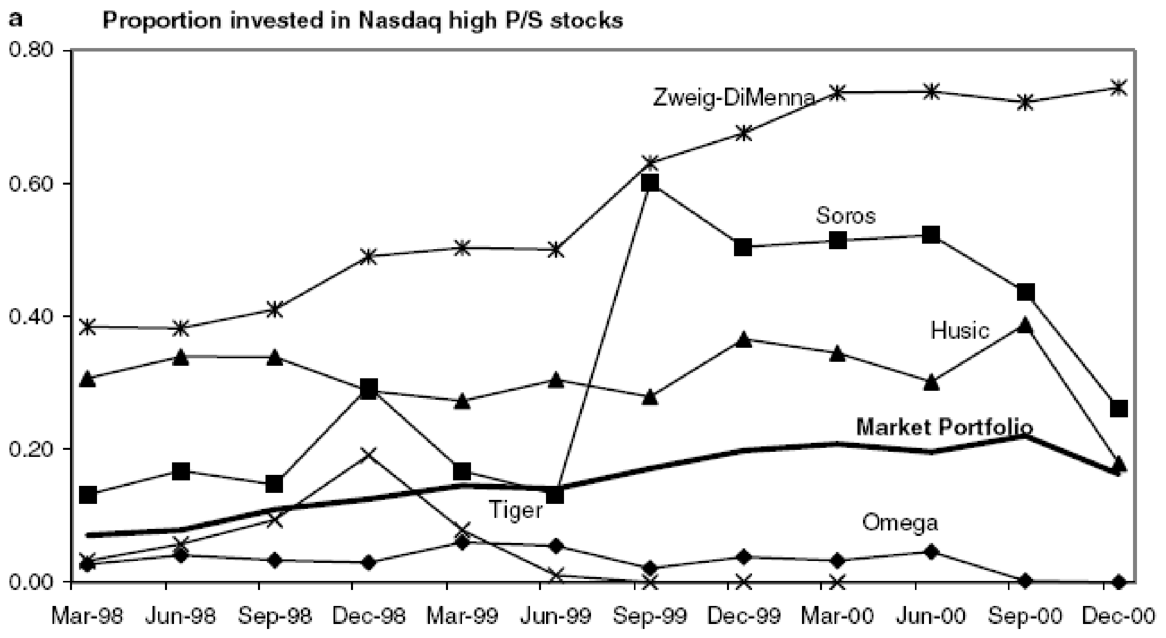
- Compare HFs' long portfolio weight in high P/S stocks against the market-portfolio weight of the same stocks



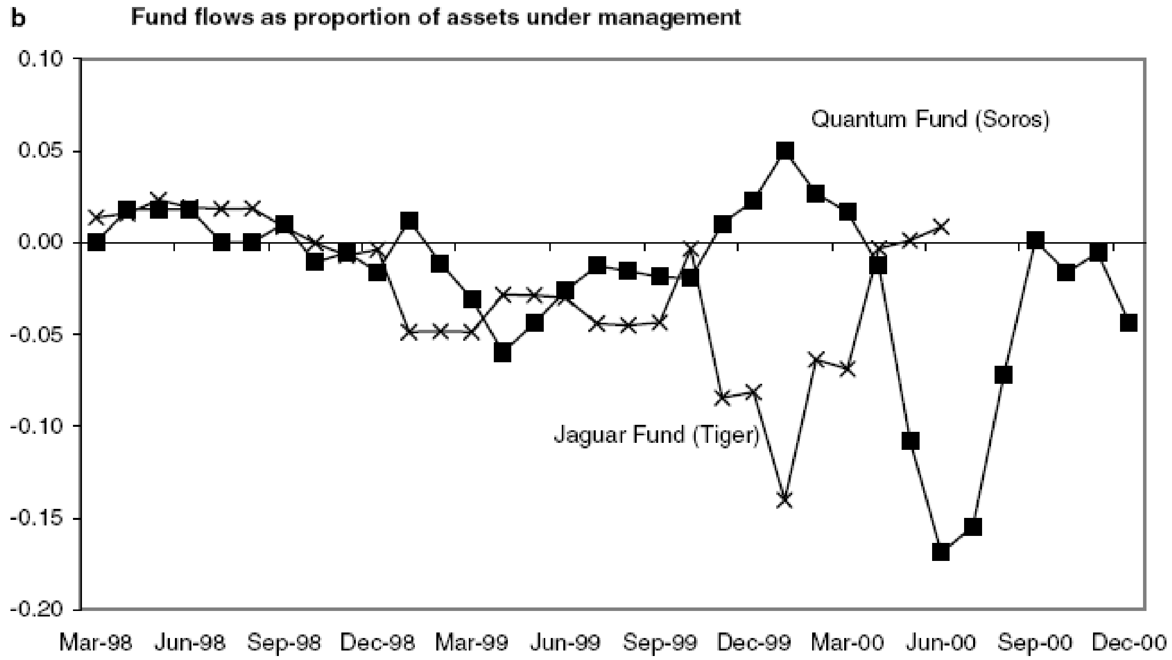
- **HFs were overweight** in tech stocks at least until the Nasdaq peak (March 2000): they were **riding the bubble**, not attacking it
  - Consistent with **synchronization risk** (Abreu and Brunnermeier, 2002, 2003)
- No evidence that they were increasing short exposure

Evidence for individual HFs

- Aggregate results so far; now zoom into **individual funds**
- Focus on contrasting cases: **Soros** (■) — rode the bubble; **Tiger** ($\times$) — value manager who refused to hold tech stocks
- What were the consequences for their performance and investor flows?



- **Soros**: rode the bubble aggressively, especially after June 1999 — received strong **positive inflows**
- **Tiger**: refused to chase tech stocks; exposure went to *zero* by June 1999; suffered severe **redemptions** as a result of underperformance



- **Tiger was liquidated in March 2000** — just as the bubble burst — because its asset base had eroded too much
  - A stark illustration of **Shleifer and Vishny (1997)**: losses trigger redemptions that force the rational arbitrageur out of the market at exactly the wrong moment

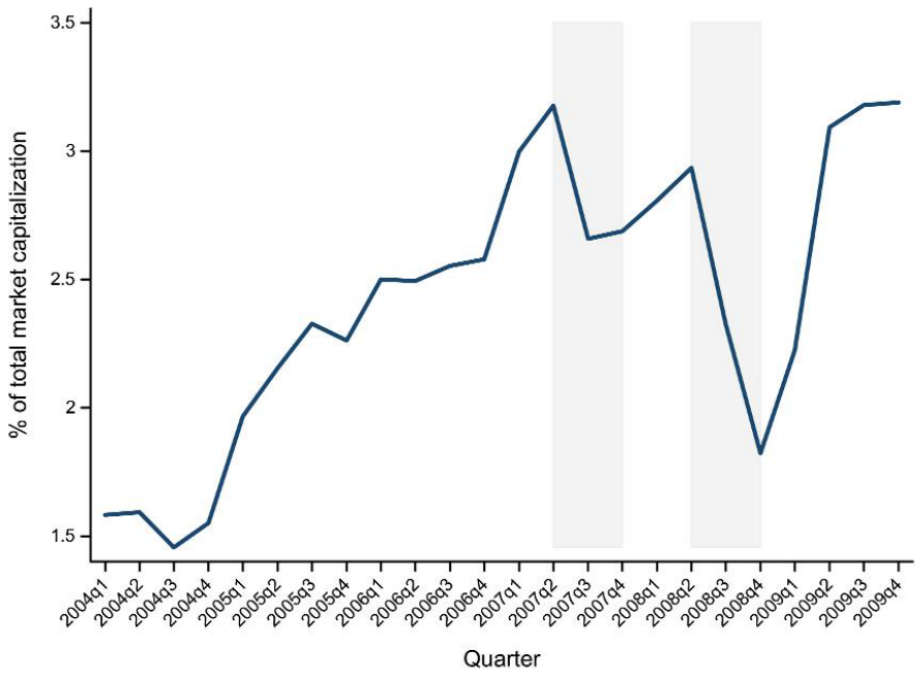
Conclusions

- In aggregate, **HFs rode the bubble** — consistent with **synchronization risk** (Abreu and Brunnermeier, 2002, 2003): arbitrageurs rationally delay correction when they cannot coordinate and can decide to ride the bubble
- The Tiger episode illustrates **limits on equity capital** (Shleifer and Vishny, 1997): temporary losses trigger redemptions that prevent arbitrageurs from holding a strategy that would eventually pay off
- **Key lesson**: mispricing can persist not because arbitrageurs are irrational, but because short horizon makes it too *costly* for them to attack it

Ben-David, Franzoni, Moussawi (2012, RFS)

- Hedge funds (HFs) resemble the **textbook arbitrageur**:
  - Sophisticated: trade across assets and markets
  - Use **leverage**
  - Engage in **short selling**
- Yet HFs depend on **outside financing**, making them vulnerable to:
  - **Investor redemptions** of capital
  - **Margin calls** from prime brokers
- **Research question**: did HFs continue to provide liquidity during the 2007–2009 financial crisis, or did they **hit financial constraints and withdraw**?

Results: HF trading



- **Data**: 13F filings (as in Brunnermeier and Nagel 2004)

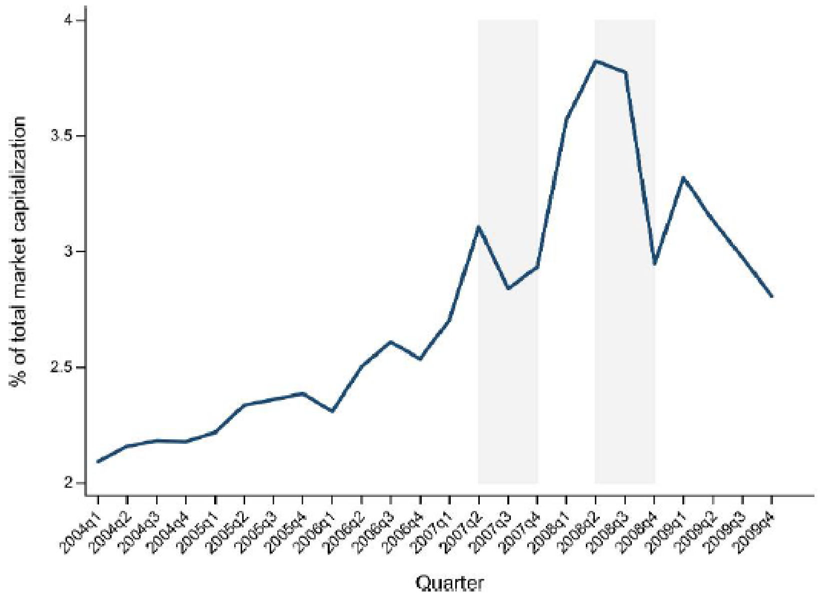
- **Drastic declines** in HF equity ownership around two periods of high tension in markets: Q3-Q4 2007, Q3-Q4 2008

- Then, they went back into the market

		Avg Qtr Δ Holdings Hedge Funds	
		%	% of total mktcap
		(1)	(2)
Pre-crisis	2004Q1-2007Q2	6.13	0.13
Crisis	2007Q3-2009Q1	-3.06	-0.10
Post-crisis	2009Q2-2009Q4	5.60	0.17
Selloff quarter	2007Q3	-9.87	-0.31
Selloff quarter	2007Q4	-2.74	-0.08
	2008Q1	4.72	0.13
	2008Q2	3.57	0.10
Selloff quarter	2008Q3	-16.70	-0.49
Selloff quarter	2008Q4	-14.26	-0.33
	2009Q1	13.88	0.25

- In the selloff quarters of 2007 and 2008, HFs decrased stock holdings by 12% and 31%, respectively

What about the short side?



- Use **exchange-reported short interest** at the stock level to proxy for HF short positions
- **High correlation** between short interest and HF long equity holdings: 42% overall, **79% during the crisis**
- **Long and short positions moved in tandem**: evidence of an overall **reduction in the size of HFs' balance sheet** rather than strategic repositioning from long to short

Net effect?

- Do changes in short positions offset changes in long positions, leaving **net liquidity provision unchanged**?

- **No**: stock-level correlation between changes in long and short positions is at most **9%**

- **Net effect on pricing**: liquidity is *removed* from stocks HFs hold ("*undervalued*") and *added* to stocks HFs short ("*overvalued*")

- **Conclusion**: the exit of HFs and short-sellers **goes in the direction of increasing mispricing**

Why did HFs sell?

- Decompose the drivers of HF selling via the balance-sheet identity:

Assets	Liabilities
U.S. Stocks	Equity (AUM)
Other investments (including Cash)	Debt (including Short positions)

$$\Delta\text{U.S. Stocks} = \Delta\text{AUM} + \Delta\text{Debt} - \Delta\text{Other Investments}$$

- **Fund flows** (ΔAUM) are observable from TASS, but:
  - No time-series data on **leverage**
  - No direct data on **other investments** (non-U.S. equity)
  - No fund-level data on **short positions**
- Empirical proxies are needed to identify channels beyond ΔAUM

Financial constraints

- Test whether the large selloffs were driven by **financial constraints**:
  - **Investor redemptions**
  - **Margin calls** (leverage-induced forced deleveraging)
  - **Risk management constraints** (VaR limits, volatility targets)

Investor Redemptions

	Dependent variable: Δ HF equity portfolio (%)	
Selloff quarter	−11.529***	−6.516
	(−4.130)	(−1.718)
Fund flows		0.160
		(0.874)
lead(Fund flows)		0.396***
		(3.892)
lead2(Fund flows)		0.157*
		(2.036)
Observations	2053	2053
Adj R^2	0.009	0.038

- Fund-quarter level regressions; dependent variable: % change in equity portfolio value; selloff-quarter dummy: Q3/Q4 of 2007 and 2008
- **Future fund flows explain 43% of the selloff dummy**
  - Future flows matter because investors must give *advance notice* of withdrawals — so today's selling anticipates tomorrow's redemptions
- **Most direct evidence** of selling driven by investor withdrawals

Margin calls + Risk limits

	Dependent variable: Δ HF equity portfolio (%)		
Selloff quarter	−12.118***	−6.991	−2.653
	(−4.445)	(−1.564)	(−0.544)
× Avg. leverage		−5.982**	−5.711***
		(−2.281)	(−2.903)
Fund flows			0.193
			(1.461)
lead(Fund flows)			0.384**
			(2.400)
lead2(Fund flows)			0.060
			(0.954)
Avg. leverage		4.476***	4.326***
		(4.293)	(4.382)
Observations	1332	1332	1332
Adj R^2	0.009	0.016	0.039

- **Conjecture**: higher leverage → higher probability of forced deleveraging; confirmed by the data
- **Combined explanatory power**: financial constraints (redemptions + leverage) explain **78% of selloffs**

Which stocks are sold?

- **Stock characteristics reveal selling motives**. During the crisis, HFs sold:
  - **High-volatility** stocks (not low-volatility)
    - Consistent with **margin calls and risk management** (Brunnermeier and Pedersen 2009): high-volatility stocks require more collateral
  - **Low price-impact** stocks (not high price-impact)
    - Consistent with **management of price impact** during fire sales: sell what you can without moving the price
- Short interest was also closed predominantly on **high-volatility stocks**
- **Overall**: evidence is consistent with the **financial constraints channel**

HFs vs. Mutual Funds

- Use **mutual funds (MFs)** as a benchmark for HF behavior
- **Similarities**: both invest actively in equity markets
- **Key differences** that matter for limits of arbitrage:
  - HFs use **high leverage** and **short positions**
  - HFs have **lock-up periods** restricting capital withdrawals
  - HF investors are more **sophisticated** (predominantly institutional)

Difference in behavior

Panel A: Summary Statistics for Hedge Funds

	Hedge funds		
	Quarterly returns (%)	Trades/Total equity portfolio (%)	Flows/AUM (%)
	(1)	(2)	(3)
2007Q3	−0.09	−9.87	5.71
2007Q4	1.84	−2.74	−6.21
2008Q1	−2.57	4.72	−1.80
2008Q2	3.05	3.57	8.06
2008Q3	−9.78	−16.70	1.64
2008Q4	−9.12	−14.26	−8.87
2009Q1	0.11	13.88	−24.35

Panel B: Summary Statistics for Mutual Funds

	Mutual funds		
	Quarterly returns (%)	Trades/Total equity portfolio (%)	Flows/AUM (%)
	(1)	(2)	(3)
2007Q3	1.86	0.75	0.79
2007Q4	−2.39	1.34	0.46
2008Q1	−8.90	−0.52	0.08
2008Q2	0.15	−1.70	0.79
2008Q3	−11.12	−0.12	0.59
2008Q4	−22.13	−0.24	−0.92
2009Q1	−7.97	1.86	−0.92

- Compared to HFs, MFs experienced:
  - **Lower redemptions**
  - **Much lower equity sales** (MFs barely sold at all)
- **Implication**: it was specifically the **leverage and short-selling structure** of HFs — not general investor sentiment — that caused the crisis-period selloffs

Conclusions

- HFs **drastically reduced equity holdings** during the 2007–2009 crisis; the main drivers were **capital withdrawals** and **lender pressure**
- HFs are distinctive because:
  - **Investors react aggressively to past losses**, triggering outflows
  - Stronger selloffs for HFs with more **institutional investors** (who are more performance-sensitive)
- **Strong support for limits to arbitrage** in bad times: Shleifer and Vishny (1997), Gromb and Vayanos (2002), Brunnermeier and Pedersen (2009)
- HF liquidity provision appears to be **pro-cyclical**: they withdraw precisely when markets need them most (also Cotelioglu, Franzoni, and Plazzi, 2021)

Coval and Stafford (JFE 2007)

- Focus on **fire sales** (Shleifer and Vishny, 1992, 2011): a forced sale of an asset **below its best-use valuation**

- **When do fire sales arise?** When asset holders must return cash to capital providers (shareholders or creditors) and cannot raise it otherwise; and when other *specialized* holders of the same asset are also in distress and therefore **sidelined** as buyers

- As a result, the asset is sold to **lower-valuation buyers**, depressing the price below fundamentals

- **Price pressure from fire sales is indirect evidence of limits of arbitrage**: if markets were frictionless, deep-pocketed investors would immediately absorb the supply

- **Identification strategy**: focus on stock sales by mutual funds experiencing large **capital outflows (redemptions)** — an exogenous reason to sell, unrelated to the value of the assets being sold

Identifying fire sales

- Funds experiencing **outflows reduce positions** more than other funds; symmetrically, funds with **inflows increase positions**

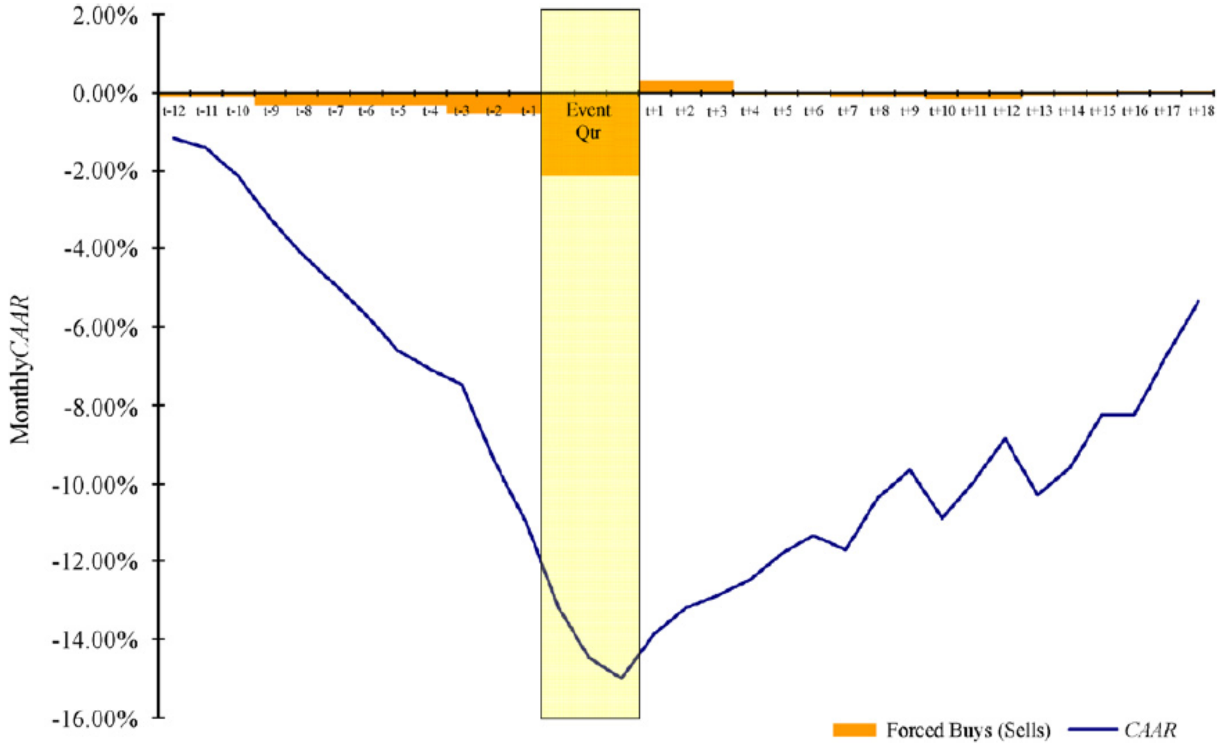
- Define a **flow-induced price pressure** measure for stock i in quarter t: net buying by top-decile inflow funds minus net selling by bottom-decile outflow funds, scaled by average trading volume:

$$PRESSURE\_1_{i,t} = \frac{\sum_j \left(\max\left(0, \Delta Holdings_{j,i,t}\right) | flow_{j,t} > Percentile\left(90th\right)\right)}{AvgVOLUME_{i,t-12:t-6}} - \frac{\sum_j \left(\max\left(0, -\Delta Holdings_{j,i,t}\right) | flow_{j,t} < Percentile\left(10th\right)\right)}{AvgVOLUME_{i,t-12:t-6}} \quad (4)$$

- **Fire sale stocks**: those in the **bottom decile** of $PRESSURE\_1_{i,t}$ — most heavily sold by outflow-driven funds relative to volume

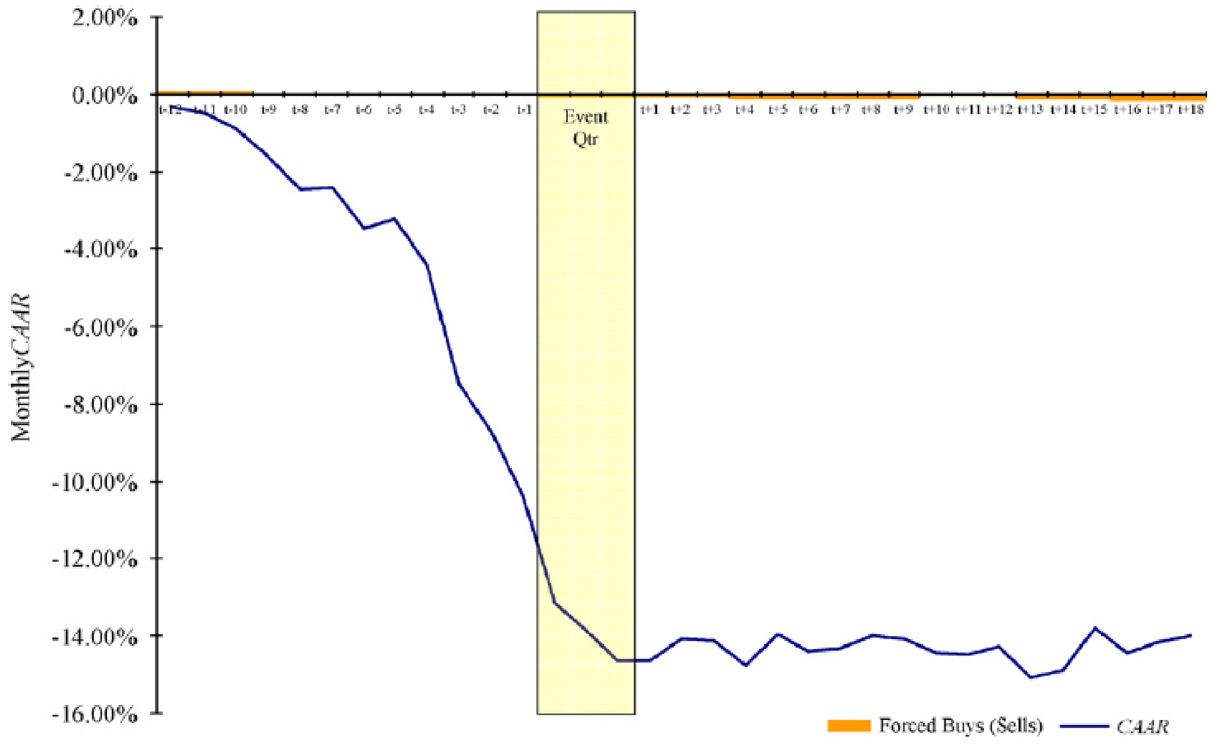
Price behavior of fire sale stocks

- **Key identification assumption**: *fire-sale* price pressure reverts; *information-driven* price declines are permanent
- Price pattern for **flow-induced fire sale stocks** (bottom decile by $PRESSURE\_1_{i,t}$), averaged across stocks and quarters:



- **Price reverts** — consistent with non-fundamental pressure and limited arbitrage. Magnitude: -7.9% abnormal return over the two quarters through month t (t-stat $= -3.45$); **full reversal takes $\sim$18 months** — a very slow correction

- **Counterfactual**: for *voluntary* sales (constructing the pressure variable without conditioning on fund flows), the price pattern is:



- **No reversal** — consistent with **information-driven sales**: prices stay low permanently

- Note: even flow-driven fire sale stocks show *pre-event* price declines. Two explanations:
  - **Persistent outflows**: funds were already selling in prior quarters due to earlier redemptions
  - **Feedback loop**: prior price declines generate poor fund performance $\rightarrow$ redemptions $\rightarrow$ forced selling

- **Concerns about the exogeneity** of the fire sales. **The funds can choose** which stocks to liquidate

Possible explanations

- Why does full price reversal take $\sim$18 months? Duffie (2010) proposes two mechanisms for **slow moving capital**, both preventing **immediate** arbitrage:

  1. **Investor inattention**: some traders only participate in the market at infrequent dates (continuous monitoring is costly). Always-present investors have **limited risk-bearing capacity** and require a price concession to absorb fire-sale supply; they then gradually sell shares back to the inattentive investors as they return — generating the dip and slow reversal

  2. **Imperfect information**: the market cannot tell whether the price drop reflects *bad news* or an *exogenous forced sale*; it assigns positive probability to adverse information. Over time, as no bad news materializes, that probability is revised down and the price drifts back up

- The two stories are **observationally equivalent** to a large extent — disentangling them empirically remains an open challenge

A (maybe?) 'more exogenous' measure of price pressure

- Edmans, Goldstein, and Jiang (2012, JF) need an **exogenous** source of price pressure to study how underpricing affects takeover probability

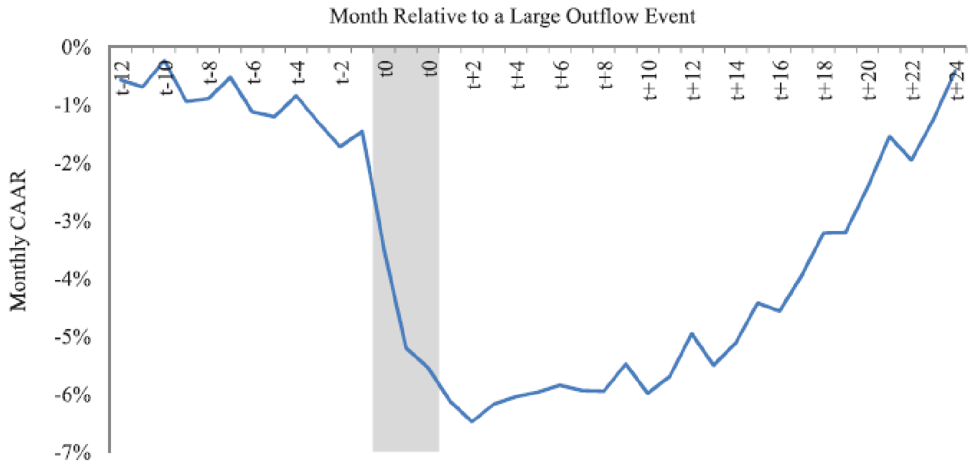
- Coval and Stafford use *actual* trades — but these may reflect **private information** about fundamentals, not just flow pressure

- EGJ instead use **hypothetical (mechanical) trades**: what would funds have sold mechanically, given their investors' flows and their *pre-period* portfolio weights?

$$MFFlow_{i,t} = \sum_{j=1}^{m} \frac{F_{j,t} \times weight_{i,t-1,j}}{VOL_{i,t}}$$

  where $F_{j,t}$ are flows into fund j, $weight_{i,t-1,j}$ is stock i's weight in fund j's prior-period portfolio, $VOL_{i,t}$ is stock volume

- EGJ find **significant price impact** followed by **slow reversal** complete only after $\sim$2 years



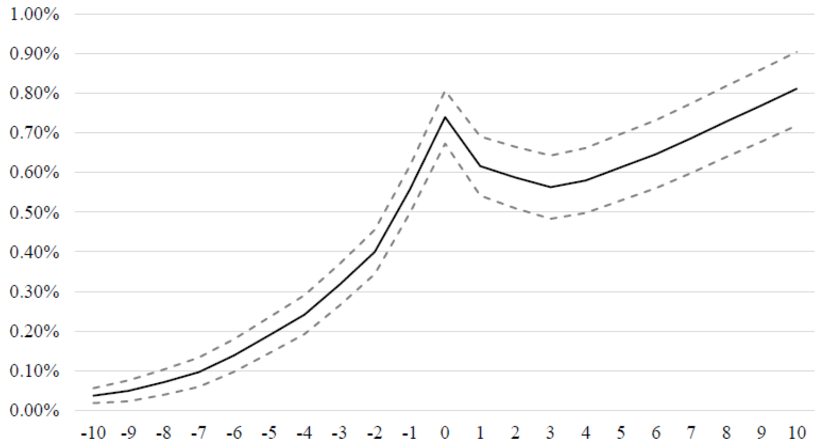
- **Wardlaw (JF, 2020) critique**: $MFFlow_{i,t}$ mechanically embeds the stock's own *contemporaneous* return
  - The numerator uses $P_{i,t-1}$ (via portfolio weights); the denominator uses $VOL_{i,t}$, which is *dollar* volume and therefore proportional to $P_{i,t}$. Their ratio embeds $P_{i,t-1}/P_{i,t} = 1/(1+r_{i,t})$, the inverse gross return, directly into the instrument
  - When flows are negative, this generates a **mechanical positive correlation** between $MFFlow_{i,t}$ and $r_{i,t}$ that **mimics the sign** of genuine fire-sale price pressure: regressing $r_{i,t}$ on $MFFlow_{i,t}$
  - After stripping out the inverse-gross-return component, the flow-pressure measure generates only a **negligible price effect** with **no reversal**

Di Maggio, Franzoni, Kogan, Xing (JF, forthcoming)

- **Building on window dressing**: investors track individual holdings $\Rightarrow$ managers have an **ex ante** incentive to **avoid positions that could produce salient losses**, not just to window-dress **ex post**

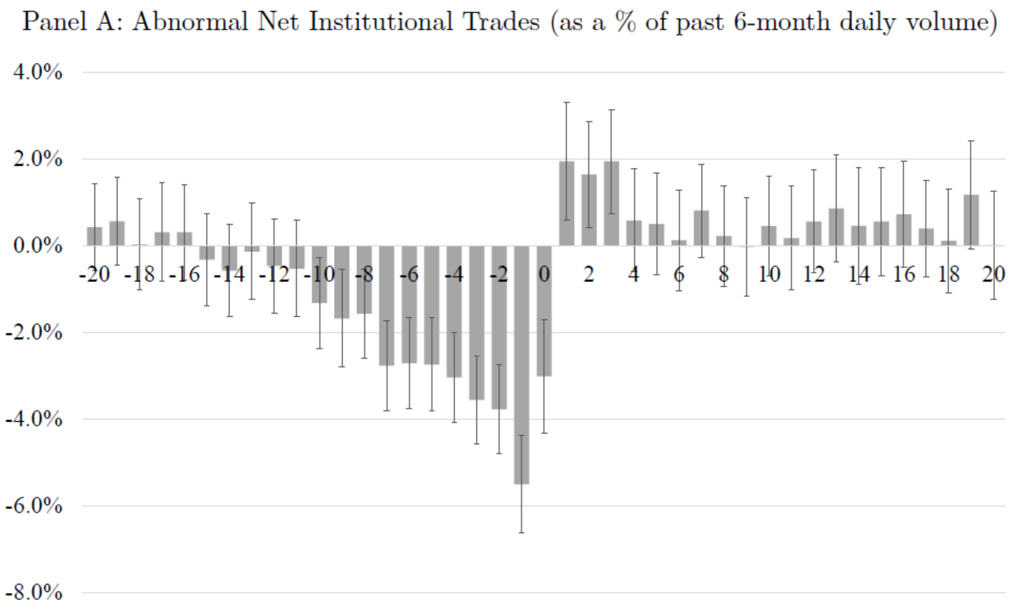
- **Ideal laboratory**: earnings announcements (EAs). The pre-EA premium is well-established (**75 bps** CAR in $[-10, 0]$; information ratio improves). But EAs feature large **idiosyncratic volatility** spikes. If investors punish managers for individual-stock losses, the risk–return tradeoff that looks attractive to an unconstrained arbitrageur looks different to a manager who fears redemptions

Panel A: DGTW Cumulative Abnormal Returns (CARs) around Earnings Announcements



Institutions sell, not buy, ahead of EAs

- **First result**: institutions have **abnormal net sales** in the 10 days before EAs (order flow $\downarrow$ $\sim$30% of their typical trading volume); they return to buying *after* the announcement



- Pattern holds for **positive, negative, and zero surprises** $\Rightarrow$ private information is not the driver

- Also present ahead of any spike in option-implied volatility $\Rightarrow$ the channel is **idiosyncratic volatility avoidance**, **not EA-specific**

- **Cross-section**: abnormal sales are larger for **high-IVOL stocks**; larger for **funds with more volatile flows, shorter lockup periods, and lower reputational capital** — i.e., funds with a more fragile capital base are most constrained

Holding-level flow-performance sensitivity

- **New finding**: controlling for total fund performance, flows react to the EA return of **individual portfolio holdings**
  - Economic magnitude ≈ **one third** of the standard portfolio-level FPS
- Sensitivity is driven by the **lowest-performing stock** in the portfolio; other percentiles are insignificant ⇒ **concave (asymmetric)** holding-level FPS — opposite to the convex portfolio-level FPS (Chevalier–Ellison 1997)
- **Pre-announcement sales of the announcing stock reduce the outflows** triggered by a very negative EA return
  - Placebo: post-announcement trades have no such effect ⇒ investors focus on pre-announcement positioning

Dependent Variable	Quarterly Fund Flow					
Independent Variables	Raw return			FFC 4 factor alpha		
	(1)	(2)	(3)	(4)	(5)	(6)
Lowest Ret[0,1] × Trades Lowest[-10, -1]	0.016**			0.021**		
	(2.23)			(2.24)		
Lowest Ret[0,1] × Trades Lowest[0, 10]		0.004			0.012	
		(0.68)			(1.61)	
SD Ret[0,1] × Signed Volume[-10, -1]			-0.114**			-0.125**
			(-2.10)			(-2.29)
Controls for the past ranks	Yes	Yes	Yes	Yes	Yes	Yes
Controls for the past returns	Yes	Yes	Yes	Yes	Yes	Yes
Controls for fund characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Quarterly Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Other control variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	768	1,103	1,926	672	781	1,704
Adjusted R-squared	0.177	0.157	0.151	0.234	0.174	0.177

- **Mechanism — salience** (Bordalo,Gennaioli,Shleifer 2022): investors evaluate the managers they invest in around salient events, such as EAs
  - Supporting evidence: EDGAR downloads of mutual fund filings spike after negative EA realizations
- **Why asymmetric?** Investors perform a **stock-level evaluation** of managers only for the funds they already hold
  - **Limited attention/search costs** make it easy to *exit* on a salient loss but hard to *enter* in a winner that they do not hold, and **limited risk bearing capacity** constrains their ability to double down on the winners they hold ⇒ asymmetry

Limit of Arbitrage: the EA Premium persists

- **Consequence for asset prices**: stocks held by funds that experienced **large unexpected redemptions** earn a **significantly larger pre-announcement premium** in the next quarter ⇒ the institutional avoidance of idiosyncratic volatility **limits arbitrage capacity** and sustains the premium

Dependent Variable	DGTW Daily Abnormal Returns [-10,-1]		
	Percentile of Flow Shocks		
	5th	10th	20th
	(1)	(2)	(3)
Dummy Flow Shock × Earnings Day	10.66**	8.20***	3.42**
	(2.26)	(2.89)	(2.12)
Control variables:			
Earnings Day	1.64***	1.44***	1.39***
	(3.18)	(2.77)	(2.59)
Dummy Flow Shock	-2.50	-0.84	-0.50
	(-0.98)	(-0.49)	(-0.53)
Stock Fixed Effects	Yes	Yes	Yes
Observations	3,738,145	3,738,145	3,738,145
Adjusted R-squared	0.001	0.001	0.001

- **Contribution**: a new dimension of limits to arbitrage operating through **idiosyncratic** flow risk

Effects of institutional trading on second moments

Limits of arbitrage allow liquidity shocks to impact the volatility of the underlying securities (see model at the beginning of these notes). Institutional ownership can impart liquidity shocks as a result of flows

- **Greenwood and Thesmar (2011)**: ownership structure generates **non-fundamental risk**
  - Stocks held by investors with more volatile trading (more volatile flows) experience more non-fundamental volatility
  - Diversified investor base $\Rightarrow$ liquidity shocks *cancel out*; concentrated ownership $\Rightarrow$ correlated selling pressure
  - **Fragility** measure: positive function of the volatility and correlation of mutual fund flows owning the stock; negative function of the number of owners — **explains 8% of future stock-level volatility**
  - **Co-fragility**: correlation of flows of mutual funds owning two stocks predicts **excess covariance** beyond standard factors

- **Anton and Polk (2014)**: Connectedness = share of total market cap of two stocks held by the *same* mutual funds; predicts **excess return correlation** (residuals from four-factor model, daily data within month)
  - Intuition: ownership by the same funds generates correlated price pressure $\Rightarrow$ correlated returns
  - Effect is stronger when connected funds experience **large flows**
  - **Identification**: exogenous variation in MF ownership from outflows caused by the **late-trading scandal (2003)**
- **Ben-David, Franzoni, Moussawi (2018)**: ETF ownership **increases stock volatility**
- **Ben-David, Franzoni, Moussawi, and Sedunov (2016)**: large institutional investors **increase stock volatility and return reversal**
  - Large institutions (e.g., BlackRock) cannot be treated as collections of independent smaller entities — **correlated behavior** via shared research or risk management causes less-diversified, higher-impact trades
  - **Identification**: BlackRock–BGI merger (2009) as exogenous shock to large-institution ownership

4. Intermediary Asset Pricing

Intermediary Asset Pricing

- The limits-of-arbitrage literature has given rise to **intermediary asset pricing**: a strand of theory in which asset prices depend on the **balance sheet health of financial intermediaries** (broker-dealers, primary dealers)

- Key papers: Adrian, Etula, and Muir (2014, JF); He, Kelly, and Manela (2017, JFE). For a recent survey, see Haddad and Muir (2025)

- **Cochrane's skepticism** ("The Habit Habit", 2016): why don't long-horizon investors (wealthy individuals, endowments, pension funds) simply buy when short-term intermediaries are forced to sell?
  - Cochrane's answer: **everyone's risk aversion rises in bad times** (habit formation) — so there is no army of patient buyers waiting on the sidelines

- **Haddad and Muir (2025) respond**: trading many assets (CDS, convertible bonds) requires **specialized expertise and infrastructure**; households and long-horizon investors are slow to enter these markets, so they are **not the marginal investors** during large, rapid price swings

Adrian, Etula, Muir (JF, 2014)

- **AEM**: add **broker-dealer leverage growth** as a second factor (alongside the market) in a two-factor pricing model

- Price of risk is **positive**, consistent with **pro-cyclical leverage**: broker-dealers expand balance sheets in good times and contract in bad times — so a unit of broker-dealer leverage exposure commands a risk premium

- The factor prices **25 FF portfolios, momentum portfolios, and Treasury portfolios** well

- **HKM (He, Kelly, and Manela, JFE 2017)**: use instead the **capital ratio of primary dealers**:

$$\eta_t = \frac{\sum_i Market\ Equity_{i,t}}{\sum_i \left(Market\ Equity_{i,t} + Book\ Debt_{i,t}\right)}$$

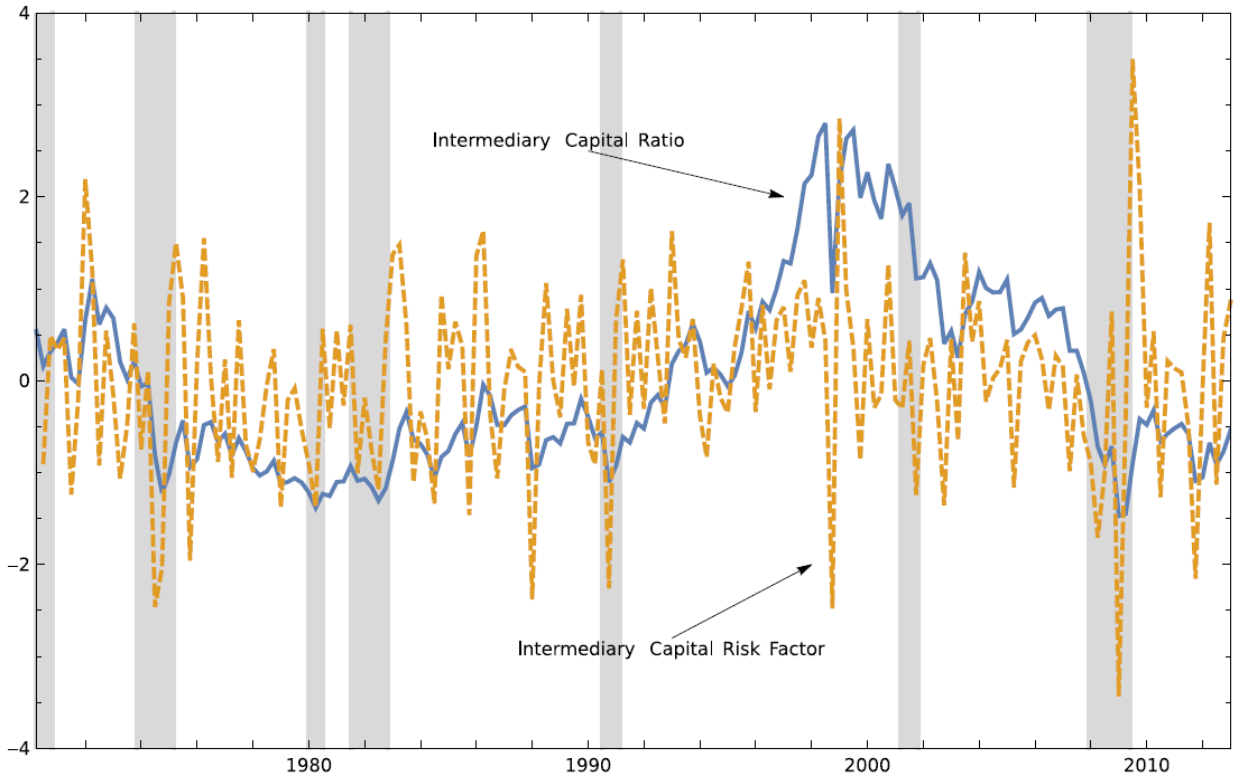
- **Primary dealers**: ≈20 institutions that are counterparties to the NY Fed in monetary policy implementation

- **Why does intermediary capital enter the pricing kernel?**

    1. Intermediaries are the **marginal investors** in many specialized markets: dealers in $\sim$95% of OTC bond transactions; top 5 dealers supply $\sim$50% of CDS protection

    2. When capital is low, intermediaries **forgo attractive opportunities** — a marginal dollar is most valuable precisely when capital is scarce

- Capital ratio is **pro-cyclical** $\Rightarrow$ positive price of risk; HKM use AR(1) innovations of η_t as the factor



- Note the sharp **drop in the capital ratio in 1998** (LTCM crisis): this shock is useful for pricing assets (e.g., options) affected by that event, though it has limited explanatory power for equities

Main Results of HKM

- In a **two-factor model** (market + intermediary capital ratio), HKM price **seven asset classes**: 25 FF portfolios, Bonds, Sovereign bonds, Options, CDS, Commodities, Currencies

	FF25	US bonds	Sov. bonds	Options	CDS	Commod.	FX	All
Capital	6.88	7.56	7.04	22.41	11.08	7.31	19.37	9.35
	(2.16)	(2.58)	(1.66)	(2.02)	(3.44)	(1.90)	(3.12)	(2.52)
Market	1.19	1.42	1.24	2.82	1.11	−0.55	10.14	1.49
	(0.78)	(0.82)	(0.32)	(0.67)	(0.41)	(−0.25)	(2.17)	(0.80)
Intercept	0.48	0.41	0.34	−1.11	−0.39	1.15	−0.94	−0.00
	(0.36)	(1.44)	(0.33)	(−0.31)	(−2.77)	(0.83)	(−0.83)	(−0.00)
R^2	0.53	0.84	0.81	0.99	0.67	0.25	0.53	0.71
MAPE, %	0.34	0.13	0.32	0.14	0.18	1.15	0.44	0.63
MAPE-R, %	0.40	0.26	0.45	0.68	0.39	1.40	0.62	0.63
RRA	2.71	3.09	2.52	8.90	3.61	2.88	8.26	3.69
Assets	25	20	6	18	20	23	12	124
Quarters	172	148	65	103	47	105	135	172

- **Price of risk is similar across asset classes** — as theory requires if the same pricing kernel governs all markets; they cannot reject the null of a common price of risk of $\approx 9\%$, but can reject 0% (the test has sufficient power)

- An *extensive* definition of intermediaries (all broker-dealers) does **worse** than using primary dealers only

- Non-financial firms' leverage has **no pricing power**

- Decomposing η_t: **equity** (numerator) drives the results more than debt (denominator)

Comparison with AEM

- **AEM** does better pricing **equities** (including momentum) and **bonds**; **HKM** does much better across **all other asset classes**
- **The puzzle**: AEM find *pro-cyclical* leverage for broker-dealers; HKM find *counter-cyclical* leverage for primary dealers (the reciprocal of the capital ratio). How can both be right?
- The difference is **not** about market vs. book leverage — the two are highly correlated
- The key is **the level of aggregation**:
  - AEM focus on individual **broker-dealer subsidiaries** within financial conglomerates — small entities that can exhibit pro-cyclical behavior
  - HKM focus on the **parent (holding company) level**: the conglomerate as a whole is a diversified entity subject to different shocks
  - The **internal capital market** of the conglomerate (ability to transfer funds across subsidiaries) is what actually determines whether the firm can absorb risky assets in bad times
  - Consistent with Franzoni and Giannetti (JFE, 2019): HFs affiliated with a financial conglomerate are **better positioned to hold risky assets in bad times**

Differences in theoretical motivation

- **Counter-cyclical leverage** (HKM): theoretical foundations in **equity-constraint models** (He and Krishnamurthy 2012, 2013; Brunnermeier and Sannikov 2014)
  - A negative shock to intermediary capital $\rightarrow$ reduced risk bearing $\rightarrow$ asset sales $\rightarrow$ further drop in equity value; with an equity constraint, debt also falls but the **equity channel dominates**
- **Pro-cyclical leverage** (AEM): theoretical foundations in **leverage-constraint models** (Gromb and Vayanos 2002; Brunnermeier and Pedersen 2009)
  - In bad times, intermediaries are **forced to reduce leverage** (e.g., by margin calls) $\rightarrow$ fire sales $\rightarrow$ amplification
- **Reconciliation**: different intermediaries face different constraints — commercial banks are more exposed to **capital ratio constraints**; hedge funds to **leverage constraints**
- The true pricing kernel is likely a **combination** of both channels, with their relative importance varying across states of the world and asset markets