Princeton Initiative
A Demand System Approach to Asset Pricing

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Traditional asset pricing

- Assume rational expectations and no constraints.
- Portfolio-choice problem for investor i:

$$\max_{\mathbf{w}_i} \mathbb{E}\left[\frac{A_{i,T}^{1-\gamma_i}}{1-\gamma_i}\right]$$

subject to $A_{i,T} = A_i(w_i(0)R(0) + \mathbf{w}_i'\mathbf{R})$.

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1. Optimal portfolio choice:

$$\mathbf{w}_i \approx \frac{1}{\gamma_i}\Sigma^{-1}\mu$$

   - Portfolio separation theorem implies homogeneous demand up to leverage (Tobin 1958).
   - Trivially rejected by data on individual or institutional portfolios.

2. Market clearing implies CAPM:

$$\mu = \mu_M \beta$$

Two literatures

1. Empirical asset pricing (CAPM and multi-factor models): Ignore micro-foundations and test equilibrium implications on price data alone.
2. Asset pricing theory: Break the portfolio separation theorem and introduce heterogeneity in asset demand.
   - Heterogeneous expectations (behavioral finance): Over-reaction, under-reaction, and extrapolative expectations.
   - Hedging motives: Uninsurable income or liability risk.
   - Career concerns and herding: Fund managers are evaluated relative to a benchmark.
   - Constraints: Investment mandates (pension funds), regulatory capital (banks and insurance companies), or leverage (hedge funds).
   - Large institutions account for price impact when they trade.

Data on portfolio holdings

1. SEC Form 13F: Quarterly U.S. stock holdings of institutions managing over $100m since 1980.
2. Thomson Reuters Ownership and FactSet Ownership: International stock holdings.
3. Thomson Reuters eMAXX: Quarterly bond holdings of institutions (mutual funds and insurance companies) since 2002.
   - Insurance companies: Schedule D since 1991.
   - Fed: System Open Market Accounts since 2003.
4. Securities Holdings Statistics: Comprehensive holdings for the euro area since 2014.
5. Household-level data from Statistics Sweden for 1983–2007 (Calvet et al. 2007).
6. Brokerage data for 1991–1996 (Barber and Odean 2000).

Questions

1. Have financial markets become more liquid over the last 30 years with the growing importance of institutional investors?
2. How much of the volatility and predictability of asset prices is explained by institutional demand?
3. Do large investment managers amplify volatility? Should they be regulated as SIFI (OFR 2013)?
4. How do large-scale asset purchases affect asset prices through institutional holdings?

Demand system asset pricing

1. A new demand system for financial assets.
   - Model asset demand as a function of characteristics.
   - Matches institutional holdings.
   - Derived from traditional portfolio choice with
     - Heterogenous beliefs.
     - Factor structure in returns.
2. IV estimator to address the endogeneity of demand and asset prices.
3. Asset pricing applications:
   - Estimate the price impact of demand shocks.
   - Explain the role of institutions in volatility and predictability.

Portfolio choice

- Portfolio-choice problem for investor i:

$$\max_{\mathbf{w}_i} \mathbb{E}_i[\log(A_{i,T})]$$

subject to $A_{i,T} = A_i(w_i(0)R(0) + \mathbf{w}_i'\mathbf{R})$.

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1. Euler equation:

$$\mathbb{E}_i\left[\left(\frac{A_{i,T}}{A_i}\right)^{-1}(\mathbf{R} - R(0)\mathbf{1})\right] = \mathbf{0}$$

2. Optimal portfolio choice:

$$\mathbf{w}_i \approx \Sigma_i^{-1}\mu_i$$

- Assumption: Covariance matrix has factor structure, where $\Sigma_i = \Gamma_i \Gamma_i' + \gamma_i \mathbf{I}$ and

$$\mu_i(n) = \mathbf{y}_i(n)'\Phi_i + \phi_i$$
$$\Gamma_i(n) = \mathbf{y}_i(n)'\Psi_i + \psi_i$$

- Proposition: Mean-variance portfolio is linear in characteristics:

$$w_i(n) = \mathbf{y}_i(n)'\Pi_i + \pi_i$$

where

$$\Pi_i = \frac{1}{\gamma_i}(\Phi_i - \Psi_i \times \text{const.})$$

Special case of mean-variance portfolio

- Specify vector of characteristics:

$$\mathbf{y}_i(n) = \begin{bmatrix} \mathbf{x}(n) \\ \log(\epsilon_i(n)) \end{bmatrix}, \Pi_i = \begin{bmatrix} \beta_i \\ 1 \end{bmatrix}$$

- Mean-variance portfolio:

$$\begin{aligned} \frac{w_i(n)}{w_i(0)} =& 1 + \mathbf{y}_i(n)' \frac{\Pi_i}{w_i(0)} \\ & \approx \exp\left\{ \mathbf{y}_i(n)' \frac{\Pi_i}{w_i(0)} \right\} = \exp\{\mathbf{x}(n)'\beta_i\}\epsilon_i(n) \end{aligned}$$

- Approximation can be made arbitrary precise through polynomial in characteristics.

Three implementations of the mean-variance portfolio

- Estimate mean-variance portfolio among stocks in the S&P 500 index, subject to short-sale constraints.
    1. Benchmark: Unrestricted mean and covariance matrix.
    2. Factor structure: Impose FF 5-factor model on mean and covariance.
    3. Characteristics: Exponential-linear function of characteristics.

Statistic	Benchmark	Factor structure	Characteristics
Mean (%)	1.1	1.5	1.5
Standard deviation (%)	4.3	6.2	5.9
Certainty equivalent (%)	1.0	1.3	1.3
Correlation:			
Factor structure	0.54		
Characteristics	0.50	0.93	

Characteristics-based demand

- Investor i allocates wealth A_i across assets in the investment universe $\mathcal{N}_i \subseteq \{1, \ldots, N\}$ and an outside asset.
- Investor i's demand for asset $n \in \mathcal{N}_i$:

$$w_i(n) = \frac{\delta_i(n)}{1 + \sum_{m \in \mathcal{N}_i} \delta_i(m)}$$

$$\delta_i(n) = \exp\left\{\beta_{0,i}\mathrm{me}(n) + \sum_{k=1}^{K} \beta_{k,i} x_k(n)\right\} \epsilon_i(n)$$

- Budget constraint implies demand for the outside asset:

$$w_i(0) = \frac{1}{1 + \sum_{m \in \mathcal{N}_i} \delta_i(m)}$$

Characteristics-based demand system

- Characteristics:
  - $x_1(n), \ldots, x_{K-1}(n)$: Log book equity, profitability, investment, dividends...
  - $x_K(n) = 1$: Constant.
  - $\epsilon_i(n)$: Unobserved characteristics.
- For example, an index fund:

$$w_i(n) = \frac{\mathrm{ME}(n)}{\exp\{-\beta_{K,i}\} + \sum_{m \in \mathcal{N}_i} \mathrm{ME}(m)}$$

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- Market clearing:

$$\mathrm{ME}(n) = \sum_{i=1}^{I} A_i w_i(n)$$

- Proposition: Unique equilibrium if demand is downward sloping for all investors (i.e., $\beta_{0,i} < 1$).

Relation to Fama-MacBeth regressions

- First-order approximation of market clearing:

$$\mathrm{me}(n) \approx \sum_{k=1}^{K} \overline{\beta}_k(n) x_k(n) + \overline{\epsilon}(n),$$

- Like a Fama-MacBeth regression, but coefficients vary across assets due to market segmentation.
- Special case: When all investors hold all assets,

$$\mathrm{me}(n) \approx \sum_{k=1}^{K} \overline{\beta}_k x_k(n) + \overline{\epsilon}(n)$$

Summary of 13F institutions

- SEC Form 13F: Quarterly stock holdings of institutions managing over $100m.
  - Types: Banks, insurance companies, investment advisors, mutual funds, pension funds, other.
  - Household sector.
- Merged with stock prices and characteristics in CRSP-Compustat.
- Big data: 44 million observations.

Period	Number of institutions	% of market held	Assets under management ($ million)		Number of stocks held		Number of stocks in investment universe	
			Median	90th percentile	Median	90th percentile	Median	90th percentile
1980–1984	544	35	337	2,666	118	386	183	523
1985–1989	780	41	400	3,604	116	451	208	692
1990–1994	979	46	405	4,566	106	512	192	811
1995–1999	1,319	51	465	6,579	102	556	176	943
2000–2004	1,800	57	371	6,095	88	521	165	983
2005–2009	2,442	65	333	5,427	73	460	145	923
2010–2014	2,879	65	315	5,441	68	447	122	800
2015–2017	3,655	68	302	5,204	67	454	112	748

Empirical specification

- Cross section of investor i's holdings:

$$\frac{w_i(n)}{w_i(0)} = \exp\left\{\beta_{0,i}\mathrm{me}(n) + \sum_{k=1}^{K}\beta_{k,i}x_k(n)\right\}\epsilon_i(n)$$

- Characteristics:
  1. Log book equity.
  2. Profitability.
  3. Investment.
  4. Dividends to book equity.
  5. Market beta.
- Estimate coefficients for each 13F institution and the household sector.
- Traditional assumption in endowment economies:

$$\mathbb{E}[\epsilon_i(n)|\mathrm{me}(n), \mathbf{x}(n)] = 1$$

Inconsistency of OLS

- Cross section of investor i's holdings:

$$\log\left(\frac{w_i(n)}{w_i(0)}\right) = \beta_{0,i}\mathrm{me}(n) + \sum_{k=1}^{K}\beta_{k,i}x_k(n) + \log(\epsilon_i(n))$$

- OLS coefficient on log market equity:

$$\widehat{\beta}_{0,i} \to \beta_{0,i} + \frac{\mathrm{Cov}(\log(\epsilon_i(n)), \overline{\epsilon}(n))}{\mathrm{Var}(\mathrm{me}(n))}$$

- OLS is consistent if
  1. Investor is atomistic.
  2. Latent demand is uncorrelated across investors.

IV estimator

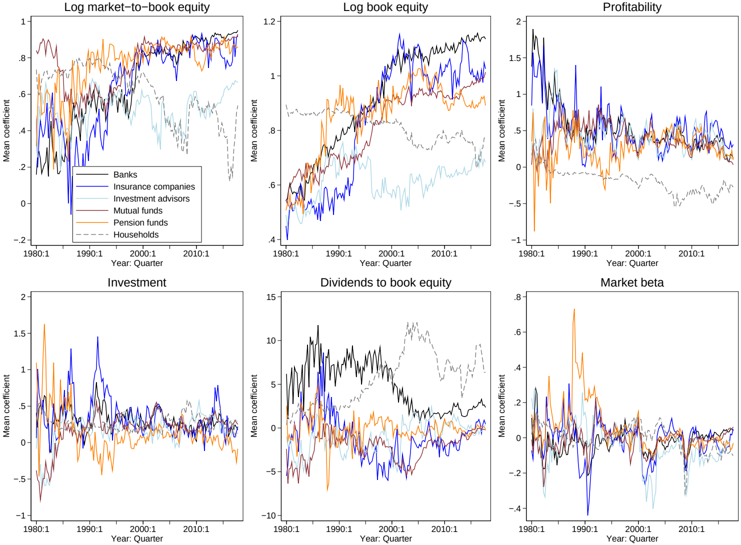
$$\frac{w_i(n)}{w_i(0)} = \begin{cases} \mathbb{1}_i(n) \exp\left\{\beta_{0,i}\mathrm{me}(n) + \sum_{k=1}^{K} \beta_{k,i} x_k(n)\right\} \epsilon_i(n) & \text{if } n \in \mathcal{N}_i \\ \mathbb{1}_i(n) = 0 & \text{if } n \notin \mathcal{N}_i \end{cases}$$

- Investors may not hold an asset for two reasons.
  1. $\epsilon_i(n) = 0$: Chooses not to hold an asset.
  2. $\mathbb{1}_i(n) = 0$: Cannot hold an asset outside the investment universe. (e.g., S&P 500 index fund has $\mathbb{1}_i(n) = 0$ for stocks outside the index).
- Assumption: Investment universe is exogenous.
- Valid instrument:

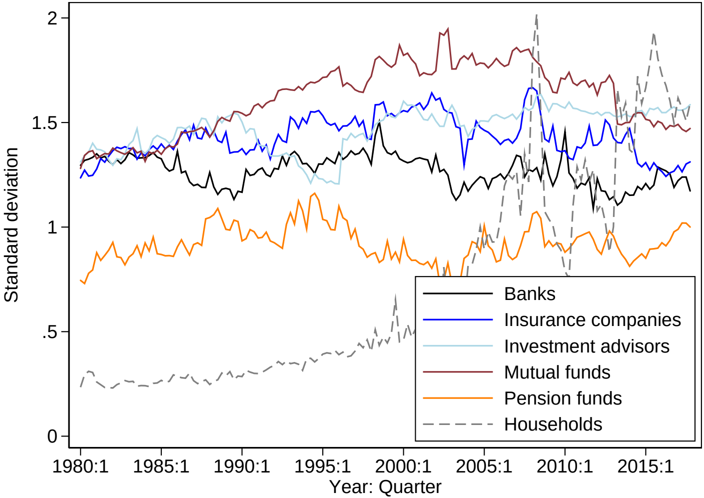
$$\widehat{\mathrm{me}}_i(n) = \log\left(\sum_{j \neq i} A_j \frac{\mathbb{1}_j(n)}{1 + \sum_{m=1}^{N} \mathbb{1}_j(m)}\right)$$

- Moment condition: $\mathbb{E}[\epsilon_i(n) | \widehat{\mathrm{me}}_i(n), \mathbf{x}(n)] = 1$

Coefficients on characteristics

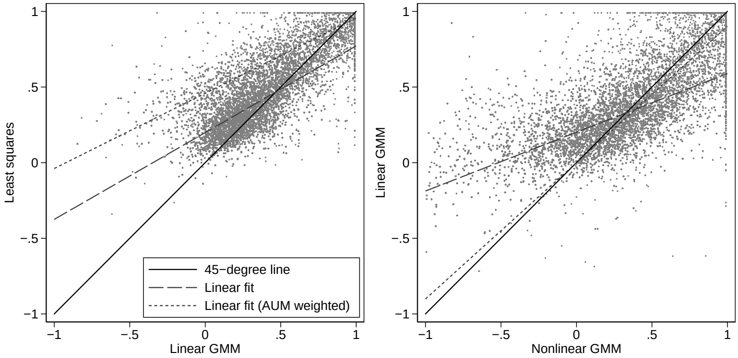


Standard deviation of latent demand



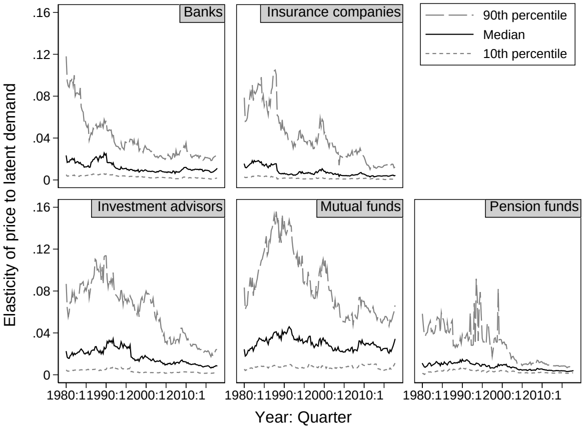
Comparison of the coefficients on log market equity

- Left: Least squares is upward biased.
- Right: Linear GMM (i.e., estimating in logs) is upward biased for smaller institutions.



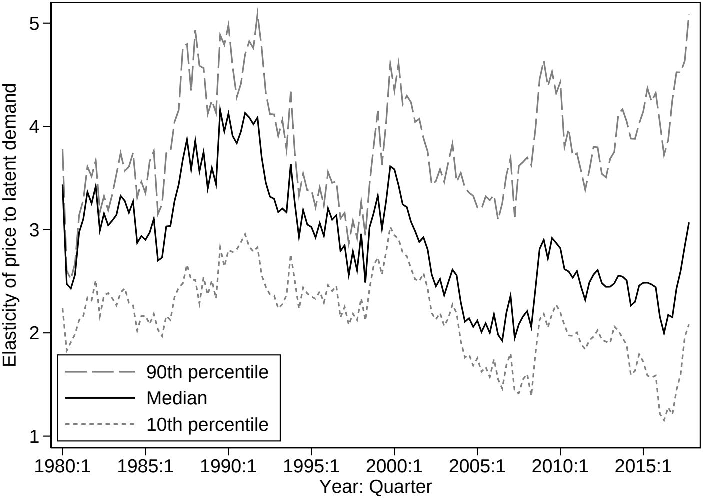
Price impact across stocks and institutions

- Price impact as a liquidity measure (Kyle 1985).
- Price impact for each investor i: $\partial p(n)/\partial \log(\epsilon_i(n))$.



Aggregate price impact across stocks

- Aggregate price impact: $\sum_{i=1}^{I} \partial p(n) / \partial \log(\epsilon_i(n))$.



Variance decomposition of stock returns

- Start with definition of log return:

$$r_{t+1}(n) = p_{t+1}(n) - p_t(n) + \log\left(1 + \frac{D_{t+1}(n)}{P_{t+1}(n)}\right)$$

- Model implies that

$$\mathbf{p}_t = \mathbf{g}(\mathbf{s}_t, \mathbf{x}_t, \mathbf{A}_t, \beta_t, \epsilon_t)$$

1. $\mathbf{s}_t$: Shares outstanding.
2. $\mathbf{x}_t$: Asset characteristics.
3. $\mathbf{A}_t$: Assets under management.
4. β_t: Coefficients on characteristics.
5. ϵ_t: Latent demand.

Variance decomposition of stock returns

	% of variance
Supply:	
Shares outstanding	2.1
	(0.2)
Stock characteristics	9.7
	(0.3)
Dividend yield	0.4
	(0.0)
Demand:	
Assets under management	2.3
	(0.1)
Coefficients on characteristics	4.7
	(0.2)
Latent demand: Extensive margin	23.3
	(0.3)
Latent demand: Intensive margin	57.5
	(0.4)
Observations	134,328

Variance decomposition of stock returns in 2008

- Are large investment managers systemic (OFR 2013)?

AUM ranking	Institution	AUM ($ billion)	Change in AUM (%)	% of variance	
	Supply: Shares outstanding, stock characteristics & dividend yield			8.1	(1.0)
1	Barclays Bank	699	-41	0.3	(0.1)
2	Fidelity Management & Research	577	-63	0.9	(0.2)
3	State Street Corporation	547	-37	0.3	(0.0)
4	Vanguard Group	486	-41	0.4	(0.0)
5	AXA Financial	309	-70	0.3	(0.1)
6	Capital World Investors	309	-44	0.1	(0.1)
7	Wellington Management Company	272	-51	0.4	(0.1)
8	Capital Research Global Investors	270	-53	0.1	(0.1)
9	T. Rowe Price Associates	233	-44	-0.2	(0.1)
10	Goldman Sachs & Company	182	-59	0.1	(0.1)
	Subtotal: Largest 30 institutions	6,050	-48	4.4	
	Smaller institutions	6,127	-53	40.7	(2.3)
	Households	6,322	-47	46.9	(2.6)
	Total	18,499	-49	100.0	

Predictability of stock returns

- Recall that

$$\mathbf{p}_T = \mathbf{g}(\mathbf{s}_T, \mathbf{x}_T, \mathbf{A}_T, \beta_T, \epsilon_T)$$

- Model ϵ_T as mean reverting and everything else as random walk.
- First-order approximation of expected long-run capital gain:

$$\begin{aligned}\mathbb{E}_t[\mathbf{p}_T - \mathbf{p}_t] \approx & \mathbf{g}(\mathbb{E}_t[\mathbf{s}_T], \mathbb{E}_t[\mathbf{x}_T], \mathbb{E}_t[\mathbf{A}_T], \mathbb{E}_t[\beta_T], \mathbb{E}_t[\epsilon_T]) - \mathbf{p}_t \\ = & \mathbf{g}(\mathbf{s}_t, \mathbf{x}_t, \mathbf{A}_t, \beta_t, \mathbf{1}) - \mathbf{p}_t\end{aligned}$$

- Intuition: Assets with high latent demand are expensive and have low expected returns.

Relation between stock returns and characteristics

Characteristic	All stocks	Excluding microcaps
Expected return	0.18	0.11
	(0.04)	(0.04)
Log market equity	-0.25	-0.15
	(0.08)	(0.08)
Book-to-market equity	0.04	0.06
	(0.04)	(0.05)
Profitability	0.30	0.29
	(0.06)	(0.06)
Investment	-0.38	-0.21
	(0.03)	(0.03)
Market beta	0.08	0.01
	(0.08)	(0.10)
Momentum	0.24	0.37
	(0.08)	(0.10)

Extensions and open issues

1. Endogenize supply (i.e., shares outstanding and characteristics) through the firm's problem.
2. Endogenize flows into institutions through the household's problem.
3. Data issues:
   - Data on aggregate short interest for NYSE, AMEX, and Nasdaq stocks.
   - Household sector is residual, but more detailed data for Sweden.
   - Linking stock and bond holdings data.
   - Fund-level data for mutual funds.

Conclusion

- Asset pricing model that matches institutional holdings.
  1. Flexible heterogeneity in asset demand.
  2. Endogeneity of demand and asset prices.
- Could answer questions that are difficult with reduced-form regressions or event studies.
- Additional questions:
  1. Which institutions drive anomalies?
  2. How does QE affect financial markets?
  3. How would regulatory reform (banks and insurance companies) affect asset prices and real investment?