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 $i$:

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

subject to $A_{i,T} = A_i(w_i(0)R(0) + w_i'R)$. 
Traditional asset pricing

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

1. Optimal portfolio choice:

$$w_i \approx \frac{1}{\gamma_i} \Sigma^{-1} \mu$$

- 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


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.
3. Thomson Reuters eMAXX: Quarterly bond holdings of institutions (mutual funds and insurance companies) since 2002.
   - Insurance companies: Schedule D since 1991.
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 $i$:

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

subject to $A_{i,T} = A_i(w_i(0)R(0) + w'_iR)$. 
Portfolio choice

- Portfolio-choice problem for investor $i$:

$$\max_{w_i} \mathbb{E}_i[\log(A_i, T)]$$

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

1. Euler equation:

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

2. Optimal portfolio choice:

$$w_i \approx \Sigma_i^{-1} \mu_i$$
• Assumption: Covariance matrix has factor structure, where
\[ \Sigma_i = \Gamma_i \Gamma_i' + \gamma_i I \] and
\[ \mu_i(n) = y_i(n)' \Phi_i + \phi_i \]
\[ \Gamma_i(n) = y_i(n)' \Psi_i + \psi_i \]

• Proposition: Mean-variance portfolio is linear in characteristics:
\[ w_i(n) = y_i(n)' \Pi_i + \pi_i \]

where
\[ \Pi_i = \frac{1}{\gamma_i} (\Phi_i - \Psi_i \times \text{const.}) \]
Special case of mean-variance portfolio

• Specify vector of characteristics:

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

• Mean-variance portfolio:

$$\frac{w_i(n)}{w_i(0)} = 1 + y_i(n)' \frac{\Pi_i}{w_i(0)}$$

$$\approx \exp \left\{ y_i(n)' \frac{\Pi_i}{w_i(0)} \right\} = \exp \{ x(n)' \beta_i \} \epsilon_i(n)$$

• 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.
  2. Factor structure: Impose FF 5-factor model on mean and covariance.

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Benchmark</th>
<th>Factor structure</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (%)</td>
<td>1.1</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Standard deviation (%)</td>
<td>4.3</td>
<td>6.2</td>
<td>5.9</td>
</tr>
<tr>
<td>Certainty equivalent (%)</td>
<td>1.0</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>Correlation:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factor structure</td>
<td>0.54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Characteristics</td>
<td>0.50</td>
<td>0.93</td>
<td></td>
</tr>
</tbody>
</table>
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 $n \in \mathcal{N}_i$:

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

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

• 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:

\[
w_i(n) = \frac{\text{ME}(n)}{\exp\{-\beta_{K,i}\} + \sum_{m \in \mathcal{N}_i} \text{ME}(m)}
\]
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:

\[
    w_i(n) = \frac{\text{ME}(n)}{\exp\{-\beta_{K,i}\} + \sum_{m \in N_i} \text{ME}(m)}
\]

- Market clearing:

\[
    \text{ME}(n) = \sum_{i=1}^{l} A_i w_i(n)
\]

- 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:
  \[ \text{me}(n) \approx \sum_{k=1}^{K} \beta_k(n)x_k(n) + \epsilon(n), \]

- Like a Fama-MacBeth regression, but coefficients vary across assets due to market segmentation.

- Special case: When all investors hold all assets,
  \[ \text{me}(n) \approx \sum_{k=1}^{K} \beta_k(n)x_k(n) + \epsilon(n) \]
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.

<table>
<thead>
<tr>
<th>Period</th>
<th>Number of institutions</th>
<th>Number of market held</th>
<th>% of</th>
<th>Assets under management ($ million)</th>
<th>Number of stocks held</th>
<th>Number of stocks in investment universe</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Median</td>
<td>90th percentile</td>
<td>Median</td>
</tr>
<tr>
<td>1980–1984</td>
<td>544</td>
<td>35</td>
<td></td>
<td>337</td>
<td>2,666</td>
<td>118</td>
</tr>
<tr>
<td>1990–1994</td>
<td>979</td>
<td>46</td>
<td></td>
<td>405</td>
<td>4,566</td>
<td>106</td>
</tr>
<tr>
<td>1995–1999</td>
<td>1,319</td>
<td>51</td>
<td></td>
<td>465</td>
<td>6,579</td>
<td>102</td>
</tr>
<tr>
<td>2000–2004</td>
<td>1,800</td>
<td>57</td>
<td></td>
<td>371</td>
<td>6,095</td>
<td>88</td>
</tr>
<tr>
<td>2005–2009</td>
<td>2,442</td>
<td>65</td>
<td></td>
<td>333</td>
<td>5,427</td>
<td>73</td>
</tr>
<tr>
<td>2010–2014</td>
<td>2,879</td>
<td>65</td>
<td></td>
<td>315</td>
<td>5,441</td>
<td>68</td>
</tr>
<tr>
<td>2015–2017</td>
<td>3,655</td>
<td>68</td>
<td></td>
<td>302</td>
<td>5,204</td>
<td>67</td>
</tr>
</tbody>
</table>
Empirical specification

• Cross section of investor $i$’s holdings:

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

• Characteristics:
  2. Profitability.
  3. Investment.
  5. Market beta.

• Estimate coefficients for each 13F institution and the household sector.

• Traditional assumption in endowment economies:

$$\mathbb{E}[\epsilon_i(n)|\text{me}(n), x(n)] = 1$$
Inconsistency of OLS

- Cross section of investor $i$'s holdings:

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

- OLS coefficient on log market equity:

$$\hat{\beta}_{0,i} \rightarrow \beta_{0,i} + \frac{\text{Cov}(\log(\epsilon_i(n)), \bar{\epsilon}(n))}{\text{Var}(\text{me}(n))}$$

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

\[
\frac{w_i(n)}{w_i(0)} = \begin{cases} 
1_i(n) \exp \left\{ \beta_{0,i} \hat{m}_e(n) + \sum_{k=1}^{K} \beta_{k,i} x_k(n) \right\} \epsilon_i(n) & \text{if } n \in N_i \\
1_i(n) = 0 & \text{if } n \notin N_i
\end{cases}
\]

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

- Assumption: Investment universe is exogenous.
- Valid instrument:

\[
\hat{m}_e_i(n) = \log \left( \sum_{j \neq i} A_j \frac{1_j(n)}{1 + \sum_{m=1}^{N} 1_j(m)} \right)
\]

- Moment condition: \( \mathbb{E}[\epsilon_i(n)|\hat{m}_e_i(n), x(n)] = 1 \)
Coefficients on characteristics

- Log market-to-book equity
- Log book equity
- Profitability
- Investment
- Dividends to book equity
- Market beta
Standard deviation of latent demand

The graph shows the standard deviation of latent demand over time for different categories of financial institutions and households. The x-axis represents the year and quarter, while the y-axis represents the standard deviation.

Categories shown include:
- Banks
- Insurance companies
- Investment advisors
- Mutual funds
- Pension funds
- Households
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 $i$: $\frac{\partial p(n)}{\partial \log(\epsilon_i(n))}$. 

![Graphs showing price impact across different institutions](image)
Aggregate price impact across stocks

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

Diagram showing the elasticity of price to latent demand from 1980 to 2015, with lines indicating the 90th, median, and 10th percentiles.
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

\[ p_t = g(s_t, x_t, A_t, \beta_t, \epsilon_t) \]

1. \( s_t \): Shares outstanding.
2. \( x_t \): Asset characteristics.
3. \( A_t \): Assets under management.
4. \( \beta_t \): Coefficients on characteristics.
5. \( \epsilon_t \): Latent demand.
### Variance decomposition of stock returns

<table>
<thead>
<tr>
<th>Source</th>
<th>Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Supply</strong></td>
<td></td>
</tr>
<tr>
<td>Shares outstanding</td>
<td>2.1 (0.2)</td>
</tr>
<tr>
<td>Stock characteristics</td>
<td>9.7 (0.3)</td>
</tr>
<tr>
<td>Dividend yield</td>
<td>0.4 (0.0)</td>
</tr>
<tr>
<td><strong>Demand</strong></td>
<td></td>
</tr>
<tr>
<td>Assets under management</td>
<td>2.3 (0.1)</td>
</tr>
<tr>
<td>Coefficients on characteristics</td>
<td>4.7 (0.2)</td>
</tr>
<tr>
<td>Latent demand: Extensive margin</td>
<td>23.3 (0.3)</td>
</tr>
<tr>
<td>Latent demand: Intensive margin</td>
<td>57.5 (0.4)</td>
</tr>
<tr>
<td>Observations</td>
<td>134,328</td>
</tr>
</tbody>
</table>
Variance decomposition of stock returns in 2008

- Are large investment managers systemic (OFR 2013)?

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

- Recall that

\[ p_T = g(s_T, x_T, A_T, \beta_T, \epsilon_T) \]

- Model \( \epsilon_T \) as mean reverting and everything else as random walk.

- First-order approximation of expected long-run capital gain:

\[
\mathbb{E}_t[p_T - p_t] \approx g(\mathbb{E}_t[s_T], \mathbb{E}_t[x_T], \mathbb{E}_t[A_T], \mathbb{E}_t[\beta_T], \mathbb{E}_t[\epsilon_T]) - p_t \\
= g(s_t, x_t, A_t, \beta_t, 1) - p_t
\]

- Intuition: Assets with high latent demand are expensive and have low expected returns.
### Relation between stock returns and characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>All stocks</th>
<th>Excluding microcaps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected return</td>
<td>0.18</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.04)</td>
</tr>
<tr>
<td>Log market equity</td>
<td>-0.25</td>
<td>-0.15</td>
</tr>
<tr>
<td></td>
<td>(0.08)</td>
<td>(0.08)</td>
</tr>
<tr>
<td>Book-to-market equity</td>
<td>0.04</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.05)</td>
</tr>
<tr>
<td>Profitability</td>
<td>0.30</td>
<td>0.29</td>
</tr>
<tr>
<td></td>
<td>(0.06)</td>
<td>(0.06)</td>
</tr>
<tr>
<td>Investment</td>
<td>-0.38</td>
<td>-0.21</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.03)</td>
</tr>
<tr>
<td>Market beta</td>
<td>0.08</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>(0.08)</td>
<td>(0.10)</td>
</tr>
<tr>
<td>Momentum</td>
<td>0.24</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>(0.08)</td>
<td>(0.10)</td>
</tr>
</tbody>
</table>
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?