In Search of a Risk-free Asset

VLADIMIR YANKOV

1Federal Reserve Board

WESTERN FINANCE ASSOCIATION ANNUAL MEETING 2013

Disclaimer: Views expressed in this research do not represent the official position of the Federal Reserve System
Outline
Stylized facts on the pricing of FDIC-insured Certificates of Deposit (CDs, time deposits) 1997-2011

1. Large and time-varying dispersion of the yields

2. Rigid yield adjustments

3. Low synchronization of yield adjustments across banks

4. Asymmetric yield adjustments to increasing/descreasing marginal costs
Outline

- Puzzle: homogeneous financial product, large number of competitors, competition in prices

- What is the role of information (search) costs on the part of the investors in this market?

- Develop a model of heterogeneous search cost investors

- Estimate and characterize the implied search cost distribution

- Rationalize the observed yield rigidity and asymmetric price adjustment
Asset pricing perspective

- Pricing of financial assets:

\[
P_{t,t+k}^f = \frac{1}{R_{t,t+k}^f} = E(M_{t,t+k}|I_t) \quad (1a)
\]

\[
0 = E(M_{t,t+1}(R_{t+1}^i - R_{t,t+1}^f)|I_t) \quad (1b)
\]

- Law of one price = No-arbitrage condition

- Large financial market: 1.2 trillion in 2007 small time deposits, part of a 6 trillion M2-M1 interest bearing substitutes, including 900 billion Retail Money Market Mutual Funds industry

- Highly competitive market: Post Regulation Q and Riegle-Neal Act, large number of commercial and savings banks, credit unions, retail money funds and low cost access to the treasury market (Treasury direct),

- Important funding source: 40 % of U.S. commercial bank assets funded by time deposits
Sources of price rigidity

- Fundamental questions in Macroeconomics:
  * Why don’t prices respond contemporaneously to aggregate conditions?*
  * How does monetary policy impact prices and allocations?*

- Source of price rigidity – **supply side**
  - State dependent: Dotsey, King and Wolman (1999)

- Source of price rigidity and monopoly power – **demand side**
Related literature

- Deposit rate rigidity / asymmetry of repricing: Diebold and Sharpe (1990), Hannan and Berger (1991), Neumark and Sharpe (1992) and Driscoll and Judson (2009)

- Costly consumer search: Stigler (1961), Burdett and Judd (1983)


- Price rigidity in a costly consumer search model: Head, Liu, Menzio and Wright (2012)

- Search costs – interpretation: Lusardi et al. (2010 a,b), Agarwal, Driscoll, Gabaix and Laibson (2009)

Stylized Facts on the Pricing of FDIC insured CDs
Data

- **CD rates**: Proprietary dataset obtained from RateWatch on retail deposit yield public offerings by 5,726 US commercial banks, 75,879 branches, over 10,000 cities, weekly observations from January 1997 to June 2011

- **Income, wealth and demographic information**: U.S. Census and BEA (MSA-level), Survey of Consumer Finance

- **Banks’ balance sheets and income statements**: Reports of Condition and Income (“Call Reports”)
The Certificate of Deposit contract: Non-price components (BRM, 2006)

Table: Contract characteristics

<table>
<thead>
<tr>
<th></th>
<th>3-month</th>
<th>6-month</th>
<th>1-year</th>
<th>2.5-year</th>
<th>5-year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Penalty (days)</strong></td>
<td>median</td>
<td>90</td>
<td>90</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td></td>
<td>mean</td>
<td>70.32</td>
<td>96.35</td>
<td>151.62</td>
<td>201.18</td>
</tr>
<tr>
<td></td>
<td>std</td>
<td>27.91</td>
<td>37.87</td>
<td>58.14</td>
<td>76.75</td>
</tr>
<tr>
<td><strong>Min. deposit amount</strong></td>
<td>median</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td></td>
<td>mean</td>
<td>1642.35</td>
<td>1444.53</td>
<td>1325.50</td>
<td>1361.67</td>
</tr>
<tr>
<td></td>
<td>std</td>
<td>1959.57</td>
<td>1721.50</td>
<td>1490.28</td>
<td>1556.77</td>
</tr>
<tr>
<td><strong>Yield</strong></td>
<td>median</td>
<td>2.86</td>
<td>3.75</td>
<td>4.00</td>
<td>3.90</td>
</tr>
<tr>
<td></td>
<td>mean</td>
<td>2.88</td>
<td>3.59</td>
<td>3.81</td>
<td>3.80</td>
</tr>
<tr>
<td></td>
<td>std</td>
<td>1.22</td>
<td>1.20</td>
<td>1.07</td>
<td>0.88</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Spearman rank correlation</th>
<th>Min.amt - yield</th>
<th>Penalty (days) - yield</th>
<th>Min.amt - penalty (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rank corr.</td>
<td>-0.10</td>
<td>-0.31</td>
<td>0.03</td>
</tr>
<tr>
<td>p-value</td>
<td>0.35</td>
<td>0.00</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>-0.01</td>
<td>-0.15</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>0.93</td>
<td>0.15</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td>0.02</td>
<td>-0.10</td>
<td>-0.19</td>
</tr>
<tr>
<td></td>
<td>0.85</td>
<td>0.31</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>-0.01</td>
<td>0.09</td>
<td>-0.21</td>
</tr>
<tr>
<td></td>
<td>0.94</td>
<td>0.41</td>
<td>-0.13</td>
</tr>
<tr>
<td></td>
<td>0.05</td>
<td>0.17</td>
<td>-0.13</td>
</tr>
<tr>
<td></td>
<td>0.63</td>
<td>0.11</td>
<td>0.22</td>
</tr>
</tbody>
</table>
The coefficient of variation
Yield dispersion: MSA level, 2003 and 2007

- Measure of price dispersion $DISP = P(90) - P(10)$ computed for 2003 and 2007, 366 MSA deposit markets

<table>
<thead>
<tr>
<th></th>
<th>2003</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P90-P10 3-month 6-month 12-month 24-month 36-month 60-month</td>
<td>P90-P10 3-month 6-month 12-month 24-month 36-month 60-month</td>
</tr>
<tr>
<td>min</td>
<td>0.04 0.16 0.24 0.19 0.07 0.00</td>
<td>0.37 0.62 0.39 0.07 0.05 0.25</td>
</tr>
<tr>
<td>p25</td>
<td>0.43 0.53 0.63 0.67 0.71 0.81</td>
<td>1.45 1.52 1.20 1.04 1.04 0.98</td>
</tr>
<tr>
<td>p50</td>
<td>0.54 0.65 0.78 0.85 0.89 0.98</td>
<td>1.88 2.00 1.47 1.31 1.25 1.17</td>
</tr>
<tr>
<td>p75</td>
<td>0.69 0.80 0.93 1.05 1.10 1.25</td>
<td>2.34 2.29 1.79 1.58 1.51 1.37</td>
</tr>
<tr>
<td>max</td>
<td>1.37 1.37 1.62 1.66 1.96 2.46</td>
<td>3.77 3.26 3.30 3.24 2.41 2.16</td>
</tr>
</tbody>
</table>

- Multi-market banks – price uniformly across markets

- Persistent yield dispersion: Among small vs large banks, “mortar-and-brick” banks vs internet banks
Fact 2: Yield rigidity

Duration in weeks between price (yield) adjustments

<table>
<thead>
<tr>
<th>Target Fed Funds</th>
<th>decreased</th>
<th>unchanged</th>
<th>increased</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p25</td>
<td>p50</td>
<td>p75</td>
</tr>
<tr>
<td>3-month</td>
<td>0</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>6-month</td>
<td>0</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>12-month</td>
<td>0</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>24-month</td>
<td>0</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>36-month</td>
<td>0</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>60-month</td>
<td>0</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>

Asymmetry of yield adjustments $D^+ = D^0 > D^-$
Fact 3: Synchronization of yield adjustments

- Fraction of adjusters

<table>
<thead>
<tr>
<th>Target Fed Funds</th>
<th>decreased</th>
<th>unchanged</th>
<th>increased</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p25</td>
<td>p50</td>
<td>p75</td>
</tr>
<tr>
<td>3-month</td>
<td>0.13</td>
<td>0.20</td>
<td>0.28</td>
</tr>
<tr>
<td>6-month</td>
<td>0.16</td>
<td>0.26</td>
<td>0.36</td>
</tr>
<tr>
<td>12-month</td>
<td>0.18</td>
<td>0.27</td>
<td>0.36</td>
</tr>
<tr>
<td>24-month</td>
<td>0.16</td>
<td>0.25</td>
<td>0.36</td>
</tr>
<tr>
<td>36-month</td>
<td>0.15</td>
<td>0.24</td>
<td>0.36</td>
</tr>
<tr>
<td>60-month</td>
<td>0.15</td>
<td>0.24</td>
<td>0.34</td>
</tr>
</tbody>
</table>

- Asymmetry of yield adjustment: $\Phi^+ = \Phi^0 < \Phi^-$
Who is the investor in FDIC insured CDs?
Participation

- SCF 2007: 16% participation rate with median investment: 20,000 USD and 2 contracts

- Participation increases with age, income and net-worth

- 45% contracts with an institution different from the main checking account

- Reasons to search: Financial advisory (e.g. BankRate.com, Google-Finance, DepositsAccount.com), CD-ladder investment strategy, binding FDIC insurance limit, Fixed maturity of contract relationship

- Role of the Internet – 41% of US HH age 55+ have no internet connection in 2006 (Census), small fraction (less than 20%) of US HH report the Internet as a main source of information for investment decisions (SCF, 2007)
Participation: Number of CD contracts / Number of institutions

Source: SCF, 2007
A model of heterogeneous search cost investors
Model: Overview

- **Banks**
  - Choose assets (loans) and liabilities (insured and uninsured)
  - Uninsured deposits: wholesale market (fed funds) with a *common* cost of funds
  - Insured deposits: Banks compete in prices following mixed strategies $F_P(P^d)$ on $S = [P_{min}, P_{max}]$

- **Investors**
  - Heterogeneous in information (search) costs $\xi \sim_d F_\xi(\xi)$
  - Search (non-sequentially) for the best (risk-adjusted) return on their savings
  - Outside option – a risky asset return

- Equilibrium concept of Burdett and Judd (1983)
Non-sequential search

- Non-sequential search: Choose $n$

$$P_{\min}(n) \equiv \min\{P_1, ..., P_n\} \sim 1 - (1 - F_P(P))^n$$

- Optimal choice of the sample size for type $\xi - n(\xi)$

$$V^d(\xi) = \max_n \left\{ - (n - 1) \times \xi + \int_{P_{\min}^{d}}^{P_{\max}^{d}} \phi^d(P_{\tau}^d)n(1 - F_P(P))^{n-1} f_P(P) dP \right\}$$

- Gain from extra search $n \to n + 1$

$$\Delta_n = \int_{P_{\min}}^{P_{\max}} \phi^d(P)(1 - F_P(P))^{n-1} \left\{ 1 - (n + 1) F_P(P)^n \right\} f_P(P) dP$$

- Optimal choice problem of type $\xi$ redefined:

$$n^*(\xi) = \arg\max_{n \in \mathbb{N}} \left\{ \Delta_n \text{ s.t.} \Delta_n \geq \xi \right\}$$
Market segmentation

- The market becomes segmented according to the intensity of search

  "Uninformed" investors: \( q_1 = 1 - F_\xi(\Delta_1) \)

  \[
  \vdots \quad q_k = F_\xi(\Delta_{k-1}) - F_\xi(\Delta_k) \\
  \vdots \quad q_N = 1 - \sum_{j=1}^{N-1} q_j
  \]

  "Informed" investors: \( q_N = 1 - \sum_{j=1}^{N-1} q_j \)

- Ex-post information heterogeneity among market segments

  \[
  P_{min}(k) \sim_d 1 - (1 - F_P(P))^k, \text{ for } k = 1, \ldots, N
  \]
Banks’ problem:

- Deposit demand function

\[ g^D(P^d) = (1 - h^d(P^d)) \left( \frac{1}{N} \sum_{k=1}^{N} q_k k (1 - F_p(P^d))^{k-1} \right) \]  \hspace{1cm} (4)

- Deposit profit function

\[ \pi^d(P^d \mid F_P(P^d)) = (P^d_j - \bar{P})(1 - h^d(P^d_j)) \left( \frac{1}{N} \sum_{k=1}^{N} q_k k (1 - F_p(P^d))^{k-1} \right) \]

- Symmetric Nash equilibrium in mixed strategies

\[ \pi^d(P^d \mid F_P(P^d)) = \begin{cases} \pi^{d*} & \text{if } P^d \in S \\ < \pi^{d*} & \text{if } P^d \notin S \end{cases} \]
Source of Monopoly Power

- The equilibrium price offer distribution
  - Case $q_1 = 1$: the price offer distribution is degenerate at the monopoly price $\bar{P}$.
  - Case $q_1 = 0$: The price offer distribution is degenerate at the perfectly competitive price $\tilde{P}$.
  - Case $0 < q_1 < 1$: The price offer distribution is non-degenerate

- Ratio of min/max mark-up:

$$
\frac{(P_{\min} - \tilde{P})}{(P_{\max} - \tilde{P})} = \frac{q_1}{\sum_{k=1}^{N} kq_k} \times \frac{(1 - h^d(P_{\max}))}{(1 - h^d(P_{\min}))}
$$

(5) Extensive margin

Intensive margin
Identification and estimation of the search cost distribution
Structural estimation: Maximum likelihood estimation

- Maximum likelihood problem:

\[
\max_{\Theta^p \in \Theta^p_A} \left\{ \frac{1}{M} \sum_{j=1}^{M} \ln f_P(P_j^d | \Theta^p) \right\}
\]

(6)

where \( z = F_P(P) \) implies \( P(z) = F_P^{-1}(z) \) solves

\[
(P(z) - \tilde{P})(1 - h(P(z))) \sum_{k=1}^{N} kq_k(1 - z)^{k-1} = (P_{\text{max}} - \tilde{P})(1 - h(P_{\text{max}}))q_1
\]

(7)

- By the implicit function theorem and \( \frac{\partial P(z)}{\partial z} = \frac{1}{f_P(P(z))} \)

\[
f_P(P) = \frac{\psi'(P)}{\psi(P)} \times \frac{\sum_{k=1}^{N} kq_k(1 - F_P(P))^{k-1}}{\sum_{k=1}^{N} k(k - 1)q_k(1 - F_P(P))^{k-2}}
\]

- \( \Theta^p = \{\beta, \gamma, \sigma, \{\theta_i\}_{i=1}^{p} \} \subset \Theta^p_A \) where \( F_\xi(\cdot) \approx \hat{F}_\xi(\cdot | \{\theta_i\}_{i=1}^{p}) \)
## Structural estimation

- Select one market - Chicago-Naperville-Joliet, IL-IN-WI

<table>
<thead>
<tr>
<th>Year</th>
<th>Pop.</th>
<th>Number banks</th>
<th>Deposits</th>
<th>Share 65+</th>
<th>HHI index</th>
<th>DISP 12-m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>8862719</td>
<td>259</td>
<td>7080</td>
<td>0.11</td>
<td>0.04</td>
<td>0.78</td>
</tr>
<tr>
<td>1998</td>
<td>8949190</td>
<td>256</td>
<td>8010</td>
<td>0.11</td>
<td>0.04</td>
<td>0.61</td>
</tr>
<tr>
<td>1999</td>
<td>9035654</td>
<td>260</td>
<td>8340</td>
<td>0.11</td>
<td>0.04</td>
<td>0.72</td>
</tr>
<tr>
<td>2000</td>
<td>9113234</td>
<td>252</td>
<td>9860</td>
<td>0.11</td>
<td>0.05</td>
<td>1.27</td>
</tr>
<tr>
<td>2001</td>
<td>9169580</td>
<td>258</td>
<td>10420</td>
<td>0.11</td>
<td>0.05</td>
<td>0.92</td>
</tr>
<tr>
<td>2002</td>
<td>9206032</td>
<td>253</td>
<td>11520</td>
<td>0.11</td>
<td>0.05</td>
<td>0.97</td>
</tr>
<tr>
<td>2003</td>
<td>9233303</td>
<td>293</td>
<td>21700</td>
<td>0.11</td>
<td>0.08</td>
<td>0.79</td>
</tr>
<tr>
<td>2004</td>
<td>9260676</td>
<td>292</td>
<td>21810</td>
<td>0.11</td>
<td>0.06</td>
<td>0.95</td>
</tr>
<tr>
<td>2005</td>
<td>9276302</td>
<td>266</td>
<td>23780</td>
<td>0.11</td>
<td>0.07</td>
<td>1.52</td>
</tr>
<tr>
<td>2006</td>
<td>9297749</td>
<td>263</td>
<td>25990</td>
<td>0.11</td>
<td>0.07</td>
<td>2.02</td>
</tr>
<tr>
<td>2007</td>
<td>9337140</td>
<td>264</td>
<td>27230</td>
<td>0.11</td>
<td>0.06</td>
<td>1.78</td>
</tr>
<tr>
<td>2008</td>
<td>9384555</td>
<td>262</td>
<td>28280</td>
<td>0.11</td>
<td>0.06</td>
<td>1.29</td>
</tr>
<tr>
<td>2009</td>
<td>9429498</td>
<td>259</td>
<td>29500</td>
<td>0.11</td>
<td>0.06</td>
<td>1.04</td>
</tr>
<tr>
<td>2010</td>
<td>9474363</td>
<td>241</td>
<td>29470</td>
<td>0.11</td>
<td>0.06</td>
<td>0.70</td>
</tr>
</tbody>
</table>

- Stable market structure - number of banks, HHI, share of households 65+
Estimated distribution of search costs: “Pre-Internet banking” period 1997 – 2001

Office of the Comptroller of the Currency: By year-end the end of 2001, 50 % of banks offered internet banking 2001
Estimated distribution of search costs

$\Delta_{1997-2007} = 30.4866$

$\text{Disp \ P}(90)-\text{P}(10) = 107$
Intensity of search
Total search costs and welfare
Model implied marginal cost of funds
Price rigidity
Monetary policy regimes

- Monetary policy: Changes $\tilde{R}$ in a sequence of steps of size $\kappa^\pm$

- Policy regimes:
  - Monetary policy tightening $T_+$ periods - $\tilde{R}$ increased
  - Monetary policy easing $T_-$ periods - $\tilde{R}$ decreased
  - Monetary policy neutrality $T_0$ periods - $\tilde{R}$ unchanged

- Examine the degree of incomplete pass-through $\frac{\partial P_{\text{min}}}{\partial P}$

- Examine the expected duration of prices $(D^+, D^0, D^-)$, the fraction of adjusters $(\Phi^+, \Phi^0, \Phi^-)$
Price rigidity and imperfect pass-through

- Incomplete pass-through
  - Response of $P_{\min}$ ($R_{\max}$) taking as given the reservation price $P_{\max}$ around $\sigma = 1$

  $$\frac{\partial P_{\min}}{\partial \tilde{P}} \approx 1 - \frac{q_1}{\sum_{k=1}^{N} kq_k} < 1$$

  - When $\tilde{R}$ low, $R_{\max}$ low and price dispersion is low. Incentives to search are low, hence pass-through is also lower than when $\tilde{R}$ high/price dispersion is high

  - $P_{\min,t+T_+} < \ldots < P_{\min,t+i} < \ldots < P_{\min,t}$ for $i = 1, 2, \ldots, T_+$

  - $P_{\min,t+T_-} > \ldots > P_{\min,t+i} > \ldots > P_{\min,t}$ for $i = 1, 2, \ldots, T_-$

- Price rigidity: Indifference region $\mathcal{Z}_{t+1} = S_{t+1} \cap S_t$, a new equilibrium level $\pi_{t+1}^{d*}$, no incentives to reprice
Repricing policy

- Admissible repricing policy: if $F_{P,t}(P)$ equilibrium in $t$ all banks reprice according to $P_{t+1}^*(P_t)$, then $F_{P,t+1}(P)$ is an equilibrium in $t + 1$

- Examine:

$$P_{t+1}^*(P_t, \rho) = \begin{cases} 
  P' \\
  \{P_t, P'\} \text{ with prob.}(\rho, 1 - \rho) \\
\end{cases}$$

if $P_t \notin S_{t+1}$

if $P_t \in S_{t+1}$

$$P' \sim G_{t+1}(P)$$

(8)
Asymmetric price adjustment

- The repricing policy leads to asymmetric price adjustment

- Fraction of adjusters: $\Phi^{-}_{t+i}(\rho) > \Phi^{+}_{t+i}(\rho)$

- Average duration of prices: $D^{+}(\rho) > D^{-}(\rho)$

- Monetary policy neutrality: $D^{0}(\rho) = D^{+}(\rho)$ and $\Phi^{0}_{t+i}(\rho) = \Phi^{+}_{t+i}(\rho)$
<table>
<thead>
<tr>
<th>Motivation</th>
<th>Stylized Facts</th>
<th>Model</th>
<th>Structural estimation</th>
<th>Price rigidity</th>
<th>Discussion and conclusion</th>
</tr>
</thead>
</table>

**Discussion and Conclusion**
Conclusion

- Presented evidence that costly information acquisition could rationalize the empirical facts on the pricing of FDIC insured CDs
  - Large yield (price) dispersion
  - Incomplete and asymmetric interest rate pass-through (price rigidity)

- The role of the Internet/Internet banking/Price comparison websites (BankRate, Google Finance, Yahoo Finance etc)

- Search for better yield, Post Regulation Q and the rise of retail MMMF

- Pricing of large denomination (>100 K) certificates of deposit

- The role of the deposit insurance limit for bank competition – Shy, Stenbacka and Yankov (2013)