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2. Screening Cost, Credit Risk, and the Optimal Structure of Mortgage Lending—Origin of the Subprime Mortgage Crisis

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Screening Cost, Pooling Equilibrium, and the Optimal Structure of Mortgage Lending

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Screening Cost, Pooling Equilibrium, and the Optimal Structure of Mortgage Lending

Part I. Costly Screening, Self Selection, and the Existence of A Pooling Equilibrium in Credit Markets

Part II. Screening Cost, Credit Risk, and the Optimal Structure of Mortgage Lending
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Introduction

Key Research Questions: What should be the optimal market structure of mortgage lending? Separating equilibrium or pooling equilibrium? If pooling, under what condition?

- Historically, housing finance policy is leaning towards promoting one-stop shopping where a big lender can provide credit to more than one types of borrowers. Now we have to ask whether this policy is right.
- Why did low-documentation loan succeed first and then failed?
- Why did the subprime mortgage market fail?
- Why did securitization fail?
- Is there any policy remedy?

Answer from this paper: Screening Cost
Contents

- Introduction to the problem
- Literature review and my addition
- Model setup
- Separating equilibrium
- Pooling equilibrium
  - Pooling equilibrium with non-risk-based pricing
  - Pooling equilibrium with risk-based pricing
- Discussion of result and implications
- Conclusion
E. Relatively uncharted territory
Oreska (1983), Nichols, Pennington-Cross and Yezer (2005), Cutts and Van Order (2005)
My addition to the Literature

- Propose a new framework to evaluate market structure in terms of screening cost and credit risk.

- Add differences in documentation cost of different types of borrowers to explore the possibility to let low-risk-high-documentation-cost borrower receive credit.

- Add new elements to the existing theory of costly screening and self-selection in the mortgage market, such as, fraudulent borrowers (liars), application fee and type I screening error.

- Deepen the understanding of the origin of the recent subprime mortgage crisis by demonstrating the channel that liars destroy the market.

- Generate policy implications from the perspective of screening cost on the means to evaluate and to regulate financial innovations.
## Model

<table>
<thead>
<tr>
<th>Type of borrowers</th>
<th>Share of borrowers</th>
<th>Default probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Low risk, Low doc cost</td>
<td>$s_1$</td>
<td>$D^1 \approx 0$</td>
</tr>
<tr>
<td>2. Low risk, High doc cost</td>
<td>$s_2$</td>
<td>$D^2 \approx 0$</td>
</tr>
<tr>
<td>3. High risk</td>
<td>$s_3$</td>
<td>$D^3 \gg 0$</td>
</tr>
<tr>
<td>4. Liar</td>
<td>$s_4$</td>
<td>$D^4 = 1$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of lenders (Specialized lender)</th>
<th>Application fee (cost to borrowers)</th>
<th>Screening cost (cost to lenders)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 lender to type 1 borrowers</td>
<td>$a_1$</td>
<td>$C_1 - a_1$</td>
</tr>
<tr>
<td>2 lender to type 2 borrowers</td>
<td>$a_2$</td>
<td>$C_2 - a_2$</td>
</tr>
<tr>
<td>3 lender to type 3 borrowers</td>
<td>$a_3$</td>
<td>$C_3 - a_3$</td>
</tr>
</tbody>
</table>

Note:

1. $C_2 > C_1 > C_3$. A big part of $C_2$ is documentation cost.
2. Without providing documentation, type 2 borrowers and liars look alike.
Model

<table>
<thead>
<tr>
<th>Cost to separate</th>
<th>1 from 2</th>
<th>1 from 3</th>
<th>1 from 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$C_{1-2}$ low</td>
<td>$C_{1-3}$ high</td>
<td>$C_{1-4}$ low</td>
</tr>
<tr>
<td>Cost to separate</td>
<td>2 from 1</td>
<td>2 from 3</td>
<td>2 from 4</td>
</tr>
<tr>
<td></td>
<td>$C_{2-1}$ low</td>
<td>$C_{2-3}$ high</td>
<td>$C_{2-4}$ high</td>
</tr>
<tr>
<td>Cost to separate</td>
<td>3 from 1</td>
<td>3 from 2</td>
<td>3 from 4</td>
</tr>
<tr>
<td></td>
<td>$C_{3-1}$ high</td>
<td>$C_{3-2}$ high</td>
<td>$C_{3-4}$ low</td>
</tr>
</tbody>
</table>

Therefore, $C_1$ refers to $C_{1-3}$, $C_2$ refers to $C_{2-3/4}$, $C_3$ refers to $C_{3-4}$.

- Further Assumptions:

  Competitive market
  Portfolio lenders
  Each loan amount is normalized to 1.
Borrowers self select according to expected cost of credit, which consists of interest rate and application fee.

Payoff tree of the lender

\[ \pi = (1 + R)(1 - D) - 1 - C \]

In a competitive market, the lender’s profit is zero, which yields

\[ C = (1 + R)(1 - D) - 1 \] (1)
Separating Equilibrium

Perfect Screening

\[ C = (1 + R)(1 - D) - 1 \]
Separating Equilibrium
Imperfect Screening

- The expected cost of credit to borrower $i$ at lender $j$ (denoted as $I_{ij}^i$)

$$I_{ij}^i = R_j(1 - p_j) + I_{ij}^i p_j + a_j$$

where $R_j =$ interest rate charged by lender $j$;
$p_j =$ probability of correctly identifying borrower $i$'s type at lender $j$;

- Deterrence identification probability required for self-selection:

e.g. lender 1 needs to deter type 3 borrower:

$$I_{13}^3 \geq I_{33}^3$$

i.e. $R_1(1 - p_1) + p_1(R_3 + a_3) + a_1 \geq R_3 + a_3$

which yields

$$p_1 \geq 1 - \frac{a_1}{R_3 + a_3 - R_1}$$  \hspace{1cm} (2)
Meanwhile, \( p_1 \) is assumed to be a function of screening cost \( C_1 \)

\[
p_1 = \alpha + t_1 C_1
\]  
(3)

from (2) and (3)

\[
\alpha + t_1 C_1 = 1 - \frac{a_1}{a_1 + C_3 + D_3 - C_1}
\]  
(4)

Therefore, \( C_1 \) is a decreasing function of \( a_1 \). **Screening cost is decreasing with application fee.**

e.g.

\[
0.5 + 0.7 C_1 = 1 - \frac{a_1}{a_1+0.1+0.3-C_1}
\]
Note: the lender cannot charge substantially high application fee in order to lower the screening cost (hence identification probability) to zero. In the presence of type I error (error of false rejection), if the identification probability is too low, the targeted type of borrower will not have incentive apply. So there is a lower bound of screening cost determined by the reservation interest rate of the targeted type of borrower.
Separating Equilibrium

Imperfect Screening

\[ p_j = \alpha + t_j C_j \]

\( \alpha \) depends on the information freely available in the market; 
\( t_j \) represents screening technology and the easiness of identification of a borrower.

The assumption \( C_2 > C_1 > C_3 \) leads to \( C_2^* > C_1^* > C_3^* \) if the optimal screening costs of the three lenders are similar.
Pooling Equilibrium with Non-risk-based Pricing

**Definition** \( \exists \) pooling equilibrium \( X \) iff in the following three scenarios:

Borrowers **inside** the pool: \( X = \{ x : x = j + 1, \ldots, 4 \} \)

Borrowers **outside** the pool: \( Y = \{ y : y = 1, \ldots, j \} \)

Any subset of borrowers outside the pool: \( Z \subseteq Y \).

For any set \( Z \) (including single element set), the following inside stability and outside stability conditions have to be met:

1. \( I'_p(X \cup Z) < I'_pX \)
   & \( I'_pX < I'_p(X \cup Z) \)
   & \( \text{Min}[I'_y]_{y \in Z} < I'_pX \) \& \( \text{Min}[I'_y]_{y \in Z} < I'_p(X \cup Z) \)

2. \( I'_pX < I'_p(X \cup Z) \)
   & \( I'_pX < I'_p(X \cup Z) \)
   & \( \text{Min}[I'_y]_{y \in Z} < I'_pX \) \& \( \text{Min}[I'_y]_{y \in Z} < I'_p(X \cup Z) \)

3. \( \text{Min}[I'_y]_{y \in Z} > I'_pX \)
   & \( I'_pX < I'_p(X \cup Z) \)
   & \( I'_pX < I'_p(X \cup Z) \)

Note: in computing the cost of credit \( I'_pX \), the cost of screening out \( y \) should be included.
Illustration: existence of pooling depends on screening cost and the relative share of each type of borrower

\[ C = (1 + R_p)(1 - D_{AB}) - 1 \]
Pooling Equilibrium with Non-risk-based Pricing- Perfect Screening

Exhaust every possible combinations of different types of borrowers and apply the conditions in the definition of pooling equilibrium to check the existence of pooling equilibria, and skip one hundred pages of math derivations, only the following pooling equilibria are possible:

In the most general case, the market has some liars, assuming $D_1 = D_2 = 0$, and $s_4 \neq 0$,

- when $C_1 > s_3 D^3 + s_4$, pooling of 1,2,3 and liars;
- when $C_1 < s_3 D^3 + s_4$ and $C_2 > \frac{1}{s_2+s_3+s_4} (s_3 D^3 + s_4)$ and $C_3 > \frac{1}{s_2+s_3+s_4} (s_3 D^3 + s_4) - D^3$, pooling of 2, 3 and liars;
- when $C_1 < s_3 D^3 + s_4$ and $C_2 < \frac{1}{s_2+s_3+s_4} (s_3 D^3 + s_4)$ and $C_3 > \frac{s_4}{s_3+s_4} (1 - D^3)$, pooling of 3 and liars;
- when $C_1 < \text{Min} \left[ \frac{s_4}{s_1+s_2+s_4}, s_3 D^3 + s_4 \right]$ and $C_2 > \frac{s_4}{s_2+s_4}$ and $C_3 < \text{Min} \left\{ \frac{s_4}{s_2+s_4} - D^3, \frac{1}{s_2+s_3+s_4} (s_3 D^3 + s_4) - D^3 \right\}$, pooling of 2 and liars.
Pooling Equilibrium with Non-risk-based Pricing

- So when the screening cost of a particular type of borrower exceeds certain threshold, this type of borrower will be pooled with liars, except if the screening cost for type 1 borrower is too high, the whole market will be pooled together.

- Note: pooling of 1 and 3 is possible, but highly unlikely, as it requires the condition $C_3 < s_2[a_p - s_3D^3]$, but usually $a_p - s_3D^3 < 0$.
Pooling Equilibrium with Non-risk-based Pricing

Pooling of type 1, 2, 3 and 4

\[ R_{p1234} < R_1 \]

Pooling of type 2, 3 and 4

\[ R_{p234} < R_2, \ R_{p234} < R_3, \ R_1 < R_{p1234} \]
Pooling Equilibrium with Non-risk-based Pricing

Pooling of type 3 and 4

\[ R_{p34} < R_3, \quad R_2 < R_{p234}, \]
\[ R_1 < R_{p1234} \]

Pooling of type 2 and 4

\[ R_1 < \text{Min}[R_{p124}, R_{p1234}], \]
\[ R_{p24} < R_2, \]
\[ R_3 < \text{Min}[R_{p24}, R_{p234}] \]
Pooling Equilibrium with Non-risk-based Pricing-Imperfect Screening

Because of the lower bound of screening cost (upper bound of application fee), all the results are the same as in perfect screening.
Pooling Equilibrium with Risk-based Pricing- Perfect Screening

Proposition

Under perfect screening, no pooling lender with risk-based pricing can compete with specialized lenders in the market.

Proof.

To each type of borrower within the pool, a pooling lender needs to offer a mortgage rate competitive to that of a specialized lender. However, the screening cost of the pooling lender has to be the highest among all types of borrowers within the pool. So the pooling lender is receiving the same amount of revenue as that of the specialized lender from each type of borrower while paying higher screening cost overall. So the pooling lender cannot compete with specialized lenders.

(math in appendix)
Pooling Equilibrium with Risk-based Pricing- Imperfect Screening

Proposition

Under imperfect screening, no pooling lender with risk-based pricing can compete with specialized lenders in the market.

Proof.

To each type of borrower within the pool, a pooling lender needs to offer a mortgage rate competitive to that of a specialized lender. However, the screening cost of the pooling lender has to be the highest among all types of borrowers within the pool. The pooling lender is receiving the same amount of revenue as that of the specialized lender from all types of borrowers combined while paying higher screening cost overall. So the pooling lender cannot compete with specialized lenders.

(math in appendix)
### Discussion

<table>
<thead>
<tr>
<th>Pooling with non-risk-based pricing</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Perfect Screening</strong></td>
<td><strong>Imperfect Screening</strong></td>
</tr>
<tr>
<td>when screening costs fall into different ranges pooling emerges:</td>
<td></td>
</tr>
<tr>
<td>pooling of 123(4)</td>
<td>Same as in perfect screening</td>
</tr>
<tr>
<td>pooling of 23(4)</td>
<td></td>
</tr>
<tr>
<td>pooling of 3(4)</td>
<td></td>
</tr>
<tr>
<td><strong>Some liars</strong></td>
<td></td>
</tr>
<tr>
<td>when screening costs fall into different ranges pooling emerges:</td>
<td></td>
</tr>
<tr>
<td>pooling of 1234</td>
<td>Same as in perfect screening</td>
</tr>
<tr>
<td>pooling of 234</td>
<td></td>
</tr>
<tr>
<td>pooling of 34</td>
<td></td>
</tr>
<tr>
<td>pooling of 24</td>
<td></td>
</tr>
<tr>
<td><strong>Many liars</strong></td>
<td></td>
</tr>
<tr>
<td>Separating equilibrium</td>
<td>Same as in perfect screening</td>
</tr>
<tr>
<td>Or Market shut-down</td>
<td></td>
</tr>
</tbody>
</table>

Note: pooling with risk-based pricing is not possible.
Discussion

- **Pooling equilibrium possible in the short-run but not long-run.**

  Initial market structure is separate equilibrium with no liars in the market.

  When the screening costs changes due to exogenous factors, certain pooling equilibrium emerges and the liars enter the market. Soon liars swarm into the pool. The increase of share of liars quickly raises the threshold level of the screening cost for pooling to exist.

  And further entrants of liars destroys all pooling equilibria and the market goes back to separating equilibrium (but with higher screening cost than the original separating equilibrium.) And if the new separate equilibrium is not profitable, or if the costs of credit from specialized lenders are higher than the reserved (alternative) borrowing cost of each borrower, the credit market will shut down, until some exogenous factor lower the screening cost down.
Discussion

- Automated Underwriting Software lowers the screening cost.

- Low-documentation loan is designed for borrowers with high screening cost in nature, so this financial vehicle is not sustainable.

- Securitization significantly raised the screening cost of the ultimate lender, hence liars swarmed in and destroyed the market.
Proposition

Regardless of pooling structure (non-risk-based pricing or risk-based pricing), a pooling lender can survive only when his screening cost is equal to or lower than the weighted average of the screening costs of all corresponding specialized lenders that he is competing with.

Therefore, when the policy authority evaluate any financial innovations in the future, attention should be paid to whether the new innovation can lower the screening cost instead of raising it, a lesson from the subprime mortgage crisis.
Conclusion

Key Contributions:

- Prove that separating equilibrium is the optimal market structure because of the structure of screening cost.

- Demonstrate that low-documentation loan is not a sustainable financial vehicle.

- Deepen the understanding of the origin of the recent subprime mortgage crisis by showing that no pooling equilibrium is sustainable in the long-run.

- Advance the literature by establishing the results in the environment of risk-neutral agents including liars, with adverse selection and a costly universal screening process.

- Establish some minor but important theoretical results, such as why home financing relies on debt contract; what is the role of application fee; and why two-way screening error is quintessential.

- Suggest that any policy reform or evaluation of future financial innovations should pay close attention to screening cost.