Observing Unobservables: a Disentanglement of Information Asymmetries

Andrea Manera    Alberta Pelino

Bocconi University

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Adverse Selection and Moral Hazard

Information asymmetries arise whenever one of the agents involved in a transaction has an informational advantage over the other, i.e., when an agent can hide some action or some information to her counterpart.

**Moral hazard** involves an hidden *action* (e.g. workers shirk, borrowers carry more risk)

**Adverse selection** involves some hidden *information* (e.g. unknown risk class of a borrower)
The classics

- **Akerlof, 1970**, *The Market for "Lemons": Quality Uncertainty and the Market Mechanism*
- **Stiglitz and Weiss, 1981**, *Credit Rationing in Markets with Imperfect Information*

...and so many others after them

However, a long lag of empirical studies to find these effects and no concrete success (before Karlan and Zinman) in disentangling the two components in credit markets
Empirical studies

Several recent papers provide direct tests of adverse selection, including works by *Ausubel, 1998, Cardon and Hendel, 1998* and *Toivanen and Cressy, 1998*.  

Andrea Manera, Alberta Pelino  
Bocconi University  
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Introduction

Karlan and Zinman’s experiment

Karlan and Zinman’s model

The empirics

The topic

Research Questions

- How to estimate the presence and importance of hidden information and hidden action problems in the credit market? *Which of the two* has the largest impact on defaults?

- Which *model* of information asymmetries (if any) accurately describe existing markets?
Main idea of the experiment

To isolate the effect of Moral Hazard and Adverse Selection, the main idea is to use different interest rates in the credit market.

- An offered rate $r_0$, depending on which borrowers choose to ask for a loan or not (that should isolate AS)
- A contract ($r_1$) and a future ($r_2$) rate that should isolate hidden action effects (MH)
Sample and Lender overview

- Sample: 57,533 former clients with good repayment histories from 86 predominantly urban branches. The lender assigns prior borrowers into low-, medium-, and high-risk categories, and this determines the borrower’s loan pricing and maturity options.
- 5,028 took up the offer; 4,348 of applicants were approved.
- Lender: one of the largest micro-lenders in South Africa. It competed in a "cash loan" industry segment that offers small and high interest credit to a "working poor population"
Experimental design

The experiment was conducted in three waves:
57,533 direct mail solicitations with randomly different offer interest rates sent out to former clients

1. **First offer rate** \( r_0 \).
   3 interest rates conditional on **observable** risk category of the clients 7.75% – 11.75%

2. **Surprise contract rate** \( r_1 \).
   \( r_1 \leq r_0 \) and \( r_1 < r_0 \) of 350 bp on average in 41% cases

3. **Surprise future rate** \( r_2 \).
   Second surprise for 47% of the clients: future loans interest rate \( r_2 \)

Repayment behavior observed.
Karlan and Zinman’s model

- Three interest rates: $r_0$ (offered), $r_1$ (randomly lowered), $r_2$ (future offered rate), $B = 1$
- Projects differing in the sense of second order stochastic dominance;
  \[ \theta_i \text{ is an \textbf{individual} risk parameter s.t.} \]
  \[ E(Y) = p(\theta_i, e)Y(\theta_i) = Y(e) \quad \forall i \]
- If a project succeed, the payoff is $Y(\theta_i)$, increasing in risk, with probability $p(\theta_i, e_i)$, concave and increasing in effort, decreasing in risk
- If the project succeeds, borrowers always repay the loan, that is, $Y(\theta_i) > 1 + r_0 \quad \forall i$
- The cost of default is $C_g(r_2) \geq C_b(r_2)$ depending on the future rate only, and decreasing in it; $C_g(r_2) > 1 + r_0$
Maximization

Individuals choose the **optimal effort level** $\hat{e}$ and whether to enter the accept the offer or not using a backward induction process. In the second step, the borrower, observed the actual $r_1$ and the future $r_2$, solves:

$$
\max_e p(\theta_i, e)(Y(\theta_i) - 1 - r_1 + C_b(r_2)) - e - C_b(r_2)
$$

$$
\frac{\partial}{\partial e} p(\theta_i, e) \left( Y(\theta_i) - 1 - r_1 + C_b(r_2) \right) = 1
$$

which given $p(\theta_i, e)Y(\theta_i) = \bar{Y}(e)$ can be re-written as:

$$
\frac{\partial}{\partial e} \frac{p(\theta_i, e)Y(\theta_i)}{Y(\theta_i)}(A) = \frac{\bar{Y}'(e)}{Y(\theta_i)}(Y(\theta_i) - 1 - r_1 + C_b(r_2))
$$
Where IA comes in

substituting into the maximization condition and rearranging the terms we can implicitly define \( \hat{e} \) as:

- decreasing in \( r_1 \) (Hidden Action 1, **Moral Hazard**)
- increasing in the cost of default, and therefore decreasing in \( r_2 \) (Hidden Action 2, '**Dynamic Incentive**' later on)
- decreasing in \( \theta \) (Hidden Information)

Indeed, the implicit definition of \( \hat{e} \) is:

\[
\frac{1 - \bar{Y}'(\hat{e})}{\bar{Y}'(\hat{e})} = \frac{C_b(r_2) - 1 - r_1}{Y(\theta_i)}
\]

increasing in \( e \) increasing in \( \theta_i \)

(Recall that \( \bar{Y}'(e) \) is a concave function of effort)
Adverse Selection

The decision to take up the loan will instead be based on $r_0$ through a non-negative expected profit condition. Assuming $C_b(r) < 1 + r_0$,

$$E(\Pi) = p(\theta_i, \hat{e}(\theta_i))(Y(\theta_i) - 1 - r_0 + C_b(r)) - \hat{e}(\theta_i) - C_b(r) \geq 0$$

by the envelope theorem, $\frac{d}{d\theta_i} p(\theta_i, \hat{e}(\theta_i)) = \frac{\partial}{\partial \theta_i} p(\theta_i, \hat{e})$, therefore,

$$\frac{\partial E(\Pi)}{\partial \theta_i} > 0$$

A rise in $r_0$ will cause the riskiness of the borrowers pool to increase, an idea borrowed directly from Stiglitz-Weiss model, which is equivalent to K & Z’s as far as AS is concerned.
Ingredients and agents characteristics

- A set of projects with various degrees of risk $\theta_i$, the parameters of a density function $f(Y, \theta)$ of the gross returns $Y$
- $E(Y) = p(\theta_i) Y(\theta_i) = \overline{Y}$ no longer dependent on effort
- A bank offering an interest rate $\hat{r}$
- A pool homogeneous borrowers that need to borrow an amount $B$ and pledge a collateral $C$, and,
- choose a project according to their preferences, for simplicity $U = E[\Pi(Y, \hat{r})]$
The 'riskiness' of projects

In this model (as in Karlan and Zinman) project 1 is said to be riskier than project 2 whenever project 2 stochastically dominates at the second order project 1. In the model this condition is verified when $\theta_1 > \theta_2$.

Second degree stochastic dominance

if $\theta_1 > \theta_2$, and:

$$\int_0^\infty Yf(Y, \theta_1) dY = \int_0^\infty Yf(Y, \theta_2) dY$$  \hspace{1cm} (2)$$

$$\int_0^y F(Y, \theta_1) dY \geq \int_0^y F(Y, \theta_2) dY \quad \forall \ y \geq 0$$  \hspace{1cm} (3)$$
A mean preserving spread over a uniform pdf

\[ f_2(x) = \mathbf{1}_{[-\frac{1}{2}, \frac{1}{2}]} \]
A mean preserving spread over a uniform pdf

\[ f(x) = \begin{cases} \frac{1}{6} & \text{for } -3 \leq x \leq 3 \\ 0 & \text{otherwise} \end{cases} \]

\[ f_2(x) = 1_{\left[-\frac{1}{2}, \frac{1}{2}\right]} \]

\[ f_1(x) = \frac{1}{6} 1_{[-3,3]} \]
The corresponding cdf’s

F(x)

1

F_2(x)

-1/2

1/2

x
The corresponding cdf’s

\[ F(x) = \begin{cases} 1 & x \geq \frac{1}{2} \\ F_2(x) & \frac{1}{2} > x > -\frac{1}{2} \\ F_1(x) & x \leq -\frac{1}{2} \end{cases} \]
$F_2$ stochastically dominates $F_1$
The returns

The bank’s returns

\[ \rho(Y, \hat{r}) = \min\{Y + C; (1 + \hat{r})B\} \]

The borrower’s returns

\[ \Pi(Y, \hat{r}) = \max\{Y - (1 + \hat{r})B; -C\} \]
The payoffs

**Figure 2a. Firm Profits are a Convex Function of the Return on the Project**

**Figure 2b. The Return to the Bank is a Concave Function of the Return on the Project**
The source of Adverse Selection

Theorem 1
A firm will borrow IFF $\theta > \hat{\theta}$ s.t.
$$E\Pi(\hat{\theta}, \hat{r}) = \int_0^\infty \max\{ Y - (1 + \hat{r})B, -C \} dF(Y, \hat{\theta}) = 0$$

Theorem 2
As the interest rate increases, the critical value of $\theta$, below which individuals do not apply for loans, increases.
Proof of Theorem 2

By Theorem 1, we also have:

\[ 0 = \frac{d}{d\hat{r}} \Pi(\hat{\theta}, \hat{r}) = \frac{\partial}{\partial \hat{r}} \Pi(\hat{\theta}, \hat{r}) + \frac{\partial}{\partial \hat{\theta}} \Pi(\hat{\theta}, \hat{r}) \frac{d\hat{\theta}}{d\hat{r}}, \]

that is,

\[ \frac{d\hat{\theta}}{d\hat{r}} = -\frac{\partial \Pi / \partial \hat{r}}{\partial \Pi / \partial \hat{\theta}} \]

\[ \frac{\partial \Pi}{\partial \hat{r}} = \int_0^\infty \frac{\partial}{\partial \hat{r}} (\max\{ Y - (1 + \hat{r})B, -C \}) dF(Y, \hat{\theta}) \]

\[ = \int_{(1+\hat{r})B-C}^\infty \frac{\partial}{\partial \hat{r}} (\max\{ Y - (1 + \hat{r})B, -C \}) dF(Y, \hat{\theta}) \]

\[ = -B \int_{(1+\hat{r})B-C}^\infty dF(Y, \hat{\theta}) \]
Proof of Theorem 2

hence:

\[
\frac{d\hat{\theta}}{d\hat{r}} = \frac{B \int_{(1+\hat{r})B-C}^{\infty} dF(Y, \hat{\theta})}{\partial \Pi / \partial \hat{\theta}} > 0 \quad \blacksquare
\]
Recall:

The previous result basically holds because of the following Jensen’s Inequality

If $U(x)$ is a concave function of $x$, and $X$ a random variable, then

$$E[U(X)] \leq U(E[X])$$  \hfill (2)
In other terms ... the Bank's preferences
in other terms ... the Borrower’s preferences
Adverse Selection

The decision to take up the loan will instead be based on $r_0$ through a non-negative expected profit condition. Assuming $C_b(r) < 1 + r_0$,

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A rise in $r_0$ will cause the riskiness of the borrowers pool to increase, an idea borrowed directly from Stiglitz-Weiss model, which is equivalent to K & Z’s as far as AS is concerned.
Still some theoretical issues

The model thus separates three effects on IA:

- An unambiguous effect of decreasing MH by decreasing $r_2$
- An unambiguous effect of decreasing MH by decreasing $r_1$
- An ambiguous effect from AS determined by $r_0$

Why ambiguous? Because we use local methods more 'discrete' changes in the interest rate $r_0$ may change the characteristics of the borrowers pool in terms of anticipated effort dramatically. In general, Karlan and Zinman point to the possibility that we may have some 'positive selection' that may outweigh the negative AS problem. The only way to test net effects is to move to empirical results . . .
The empirical model

\[ Y_i = \alpha + \beta_0 r_0 + \beta_1 r_1 + \beta_2 C(r_2) + X_i'\gamma + \epsilon \]

Where:

- \( Y_i \) is a measure of default
- \( C(r_2) \) is the dynamic repayment incentive (a decreasing function of \( r_2 \))
### TABLE I

**Empirical Tests of Hidden Information and Hidden Action: Full Sample**

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Mean of Dependent Variable</th>
<th>OLS</th>
<th>Standardized Index of Three Default Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Monthly Average</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proportion Past Due</td>
<td>0.09</td>
<td>0.09</td>
<td>0.09</td>
</tr>
<tr>
<td>Proportion of Months in Arrears</td>
<td>0.22</td>
<td>0.22</td>
<td>0.12</td>
</tr>
<tr>
<td>Account in Collection Status</td>
<td>0.12</td>
<td>0.12</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Dynamic repayment incentive dummy</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Hidden Action Effect 1)</td>
<td>0.005</td>
<td>0.002</td>
<td>0.006*</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.004)</td>
<td>(0.005)</td>
</tr>
<tr>
<td><strong>Dynamic repayment incentive size</strong></td>
<td>-0.019*</td>
<td>-0.000</td>
<td>-0.028**</td>
</tr>
<tr>
<td>(Hidden Action Effect 2)</td>
<td>(0.010)</td>
<td>(0.017)</td>
<td>(0.011)</td>
</tr>
<tr>
<td><strong>Offer rate (Hidden Information Effect)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.005</td>
<td>0.004</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.005)</td>
</tr>
<tr>
<td><strong>Observations</strong></td>
<td>4348</td>
<td>4348</td>
<td>4348</td>
</tr>
<tr>
<td><strong>Adjusted R-squared</strong></td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td><strong>Probability (both dynamic incentive variables = 0)</strong></td>
<td>0.06</td>
<td>0.14</td>
<td>0.15</td>
</tr>
<tr>
<td><strong>Probability (all 3 or 4 interest rate variables = 0)</strong></td>
<td>0.0004</td>
<td>0.0005</td>
<td>0.0003</td>
</tr>
</tbody>
</table>

*significant at 10%; **significant at 5%; ***significant at 1%. Each column presents results from a single OLS model with the RHS variables shown and controls for the randomization conditions: observable risk, month of offer letter, and branch. Adding loan size and maturity as additional controls does not change the results. Robust standard errors in parentheses are corrected for clustering at the branch level. “Offer rate” and “Contract rate” are in monthly percentage point units (7.00% interest per month is coded as 7.00). “Dynamic repayment incentive” is an indicator variable equal to one if the contract interest rate is valid for one year (rather than just one loan) before reverting back to the normal (higher) interest rates. “Dynamic repayment incentive size” interacts the above indicator variable with the difference between the lender’s normal rate for that individual's risk category and the experimentally assigned contract interest rate. A positive coefficient on the Offer Rate variable indicates hidden information, a positive coefficient on the Contract Rate or Dynamic Repayment Incentive variables indicates hidden action (moral hazard).

The dependent variable in columns (7) and (8) is a summary index of the three dependent variables used in columns (1)–(6). The summary index is the mean of the standardized

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Summary of the main results

- Strong evidence of Moral Hazard (it explains 13 – 21% of default in the sample)
- Weaker evidence of Hidden Information problems (Possibly because of selection on expected effort or sampling)
## Gender differences

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standardized Index of Three Default Measures</td>
<td>Standardized Index of Three Default Measures</td>
</tr>
<tr>
<td>Offer Rate</td>
<td>-0.007</td>
<td><strong>0.040</strong></td>
</tr>
<tr>
<td></td>
<td>(0.018)</td>
<td>(0.016)</td>
</tr>
<tr>
<td>Contract Rate</td>
<td><strong>0.036</strong></td>
<td>-0.020</td>
</tr>
<tr>
<td></td>
<td>(0.017)</td>
<td>(0.017)</td>
</tr>
<tr>
<td>Dynamic Repayment</td>
<td>-0.076*</td>
<td>-0.039</td>
</tr>
<tr>
<td>Incentive Indicator</td>
<td>(0.040)</td>
<td>(0.036)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.002</td>
<td>-0.246</td>
</tr>
<tr>
<td></td>
<td>(0.127)</td>
<td>(0.073)</td>
</tr>
<tr>
<td>Observations</td>
<td>2215</td>
<td>2133</td>
</tr>
</tbody>
</table>
Further research

- Study more marginal (e.g. first-time) borrowers, that may pose relatively severe hidden information problems

- Design tests that address the key confound discussed in the theoretical section: selection processes can attract types who exert less unobserved effort as well as types who are innately more risky

- Study contexts where effort can be observed (e.g., settings where firms can closely monitor employee actions and productivity)