Security & Economics — Part 7
Towards information security of market

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Outline

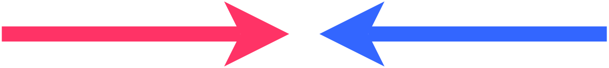
Outline

Symmetric market

Symmetric market

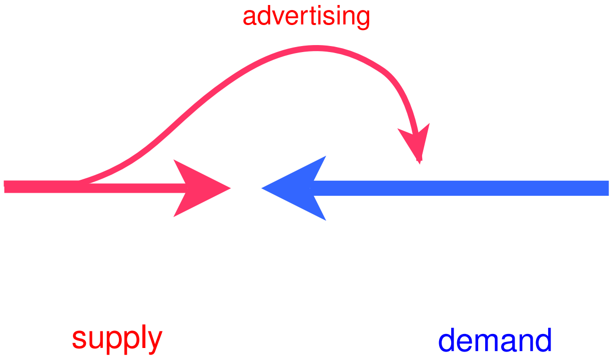
Based on trust

Symmetric market

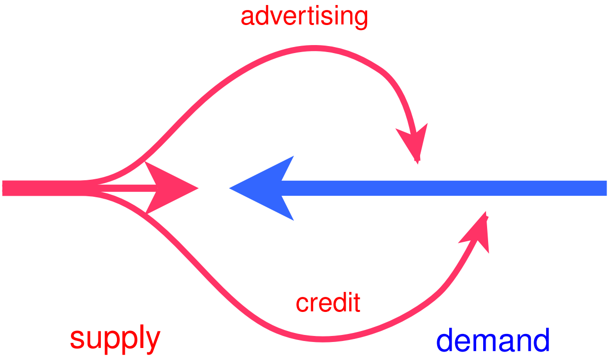


supply demand

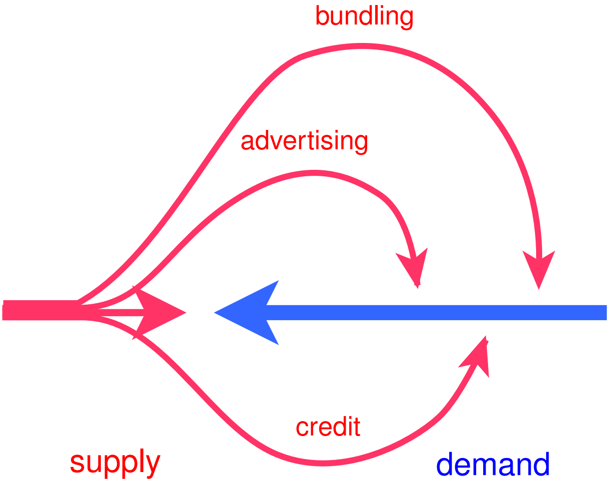
Economics of information



Economics of information



Economics of information



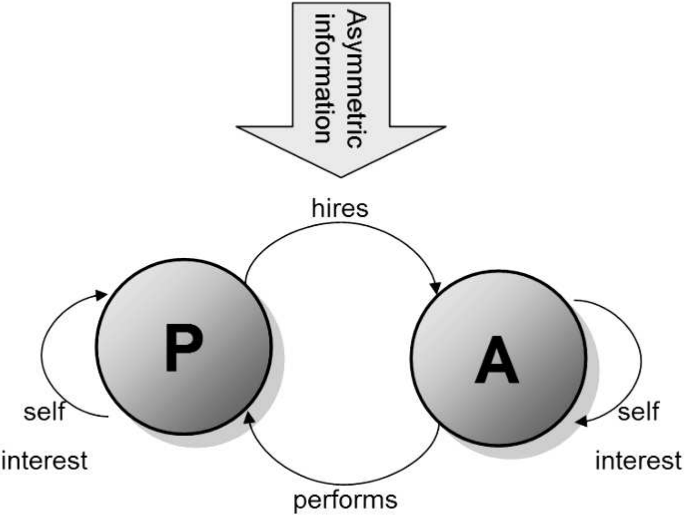
Asymmetric market

Based on influence

Moral hazard

Transferring risks: government-backed lending

Principal Agent Problem

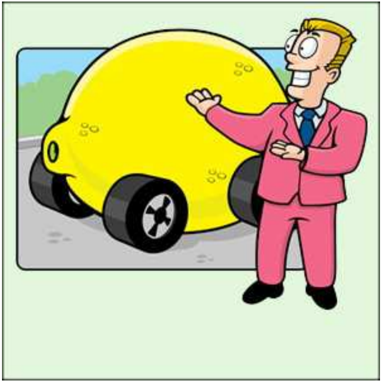


Agent acts against the Principal: bankers' bonuses

Rent Seeking

Profits on social expense: guilds, lobbying, advertising

Market of lemons



Profiting from lack of information

Phishing for phools

Creating lack of information: "Financial derivative"

Market sublimation

Upshot

- *security goal:* equilibrium of supply and demand
- *security protocol:* free exchange
- *"attacks above":* advertising, information asymmetry
  - security protocol correctly executed
  - security goal shifted

Outline

Introduction

Market of lemons

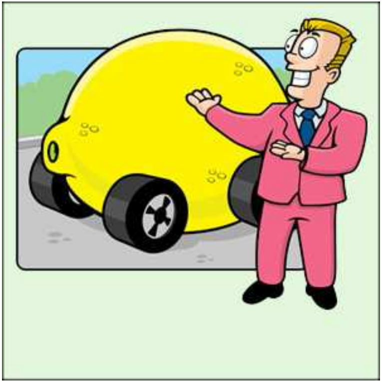
Akerloff's analysis

Expectations analysis

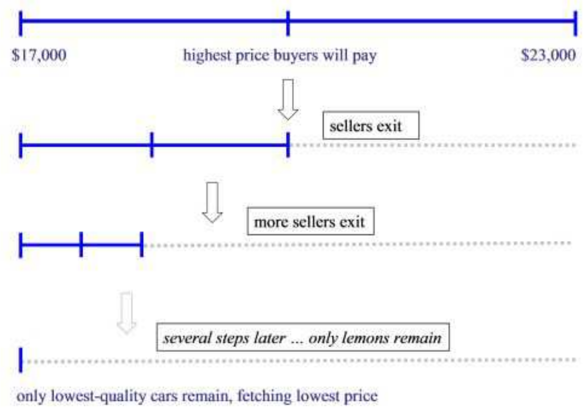
Signaling and authentication

The Efficient Market Hypothesis

Market of lemons



Market of lemons



Market of lemons: Akerloff's analysis

- valuations:

	good cars	lemons
sellers	x	0
buyers	$\frac{3}{2}x$	0

- **quality distribution**: q-fraction of cars is worth $\frac{qx}{2}$ on the average
- demand:

$$\#\text{buyers} \quad > \quad \#\text{cars for sale}$$

Market of lemons: Akerloff's analysis

1. Symmetric information

- Both sellers and buyers can tell which cars are good.
- Each good car is sold for its true value.
- The lemons are unsold or given for free.
- Since #buyers > #cars for sale, the market clears.

Market of lemons: Akerloff's analysis

2. Asymmetric information: Naive buyers

- Only sellers know which cars are good.
- The buyers
  - expect the cars with $w_0 \in \left[0, \frac{3x}{2}\right]$ uniformly distributed
  - offer the average price $p_0 = \frac{3x}{4}$.
- The sellers
  - withdraw the cars with sellers' values $v \in \left(\frac{3x}{4}, x\right]$ and
  - clear the $\frac{3}{4}$ of the cars with sellers' values $v \in \left[0, \frac{3x}{4}\right]$
- The buyers
  - get the average value $w_1 = \frac{1}{2} \cdot \frac{3}{4} \cdot \frac{3x}{2} = \frac{9x}{16}$
  - pay the average price $p_0 = \frac{3x}{4}$

Market of lemons: Akerloff's analysis

3. Asymmetric information: Rational buyers

- Only sellers know which cars are good.
- The buyers
  - expect the cars with $w_0 \in \left[0, \frac{3x}{2}\right]$ uniformly distributed
  - offer the average price $p_0 = \frac{3x}{4}$.
- The sellers
  - withdraw the cars with sellers' values $v \in \left(\frac{3x}{4}, x\right]$ and
  - clear the $\frac{3}{4}$ of the cars with sellers' values $v \in \left[0, \frac{3x}{4}\right]$
- The buyers
  - know that the values are now $w_1 \in \left[0, \frac{3}{4} \cdot \frac{3x}{2}\right] = \left[0, \frac{9x}{8}\right]$
  - offer the average price $p_1 = \frac{9x}{16}$

Market of lemons: Akerloff's analysis

3. Asymmetric information: Rational buyers

- Only sellers know which cars are good.
- The buyers
  - expect the cars with $w_1 \in \left[0, \frac{9x}{8}\right]$ uniform
  - offer the average price $p_1 = \frac{9x}{16}$.
- The sellers
  - withdraw the cars with sellers' values $v \in \left(\frac{9x}{16}, x\right]$ and
  - clear the $\frac{9}{16}$ of the cars with sellers' values $v \in \left[0, \frac{9x}{16}\right]$
- The buyers
  - know that the values are $w_2 \in \left[0, \frac{9}{16} \cdot \frac{3x}{2}\right] = \left[0, \frac{27x}{32}\right]$
  - offer the average price $p_2 = \frac{27x}{64}$

Market of lemons: Akerloff's analysis

3. Asymmetric information: Rational buyers

- Only sellers know which cars are good.
- The buyers
  - expect the cars with $w_2 \in \left[0, \frac{27x}{32}\right]$ uniformly distributed
  - offer the average price $p_1 = \frac{27x}{64}$.
- The sellers
  - withdraw the cars with sellers' values $v \in \left(\frac{27x}{64}, x\right]$ and
  - clear the $\frac{27}{64}$ of the cars with values $v \in \left[0, \frac{27x}{64}\right]$
- The buyers
  - know that the values are $w_3 \in \left[0, \frac{81x}{128}\right]$
  - offer the average price $p_3 = \frac{81x}{256}$

Market of lemons: Akerloff's analysis

3. Asymmetric information: Rational buyers

- Only sellers know which cars are good.

- $w, p \searrow 0$

- **The market collapses!**

Market of second-hand cars: Expectations

- valuations:

	good cars	bad cars
sellers	5	2
buyers	6	3

- quality: there is $a \in [0,1]$

$$\text{cars for sale} \quad = \quad a \cdot \text{good cars} + (1 - a) \cdot \text{bad cars}$$

- demand:

$$\#\text{buyers} \quad > \quad \#\text{cars for sale}$$

Market of second-hand cars: Expectations

Symmetric information

- Both sellers and buyers know which cars are good.
- Each good car is sold for $p \in [5, 6]$.
- Each bad car is sold for $p \in [2, 3]$.
- Since $\#$buyers $>$ $\#$cars for sale, the market clears.

Market of second-hand cars: Expectations

Asymmetric information

- Only sellers know which cars are good.
- Buyers estimate that

$$\text{cars for sale} \quad = \quad e \cdot \text{good cars} + (1 - e) \cdot \text{bad cars}$$

for some $e \in [0, 1]$ and they offer per car

$$p^* \quad = \quad 6e + 3(1 - e) \;=\; 3e + 3$$

Game of second-hand cars

- The buyers' determine their moves by choosing a belief $e \in [0, 1]$.
- The sellers accept to sell if their reserve prices are met.

Equilibria with asymmetric information

The cases

- belief e vs reality a
  - if $e \in (a, 1]$, then the buyers' overpay the average value of the cars
  - if $e \in [0, a]$, then the buyers don't overpay
- offer $3e + 3$ vs valuation intervals $[2, 3]$ and $[5, 6]$
  - if $e \in \left[\frac{2}{3}, 1\right]$, then $p^* = 3e + 3 \in [5, 6]$ clears all cars
  - if $e \in \left(0, \frac{2}{3}\right)$, then $p^* = 3e + 3 \in (3, 5)$ overpays the bad cars and does not get the good cars,
  - if $e = 0$, then $p^* = 3$ clears the bad cars.

Equilibria with asymmetric information

Combining the cases into equilibria

- if $e \in \left[\frac{2}{3}, a\right]$, then $p^* = 3e + 3 \in [5,6]$ clears all cars, and does not overpay them
- if $e = 0$ then $p^* = 3$ clears the bad cars, and does not overpay them

Equilibria with asymmetric information

Summary

The equilibria are

- buying all cars with $e = a$ and $p^* = 3a + 3 \in [5, 6]$, provided that $a \in \left[\frac{2}{3}, 1\right]$
- buying only bad cars with $e = 0$ and $p^* = 3$

Market with lemons: Expectations

- valuations:

	good cars	bad cars	lemons
sellers	5	2	0
buyers	6	3	0

- quality:

$$\text{all} \quad = \quad \frac{1}{3} \cdot \text{good} + \frac{1}{3} \cdot \text{bad} + \frac{1}{3} \cdot \text{lemons}$$

- demand:

$$\#\text{buyers} \quad > \quad \#\text{cars for sale}$$

Market with lemons: Expectations

Symmetric information

- Both sellers and buyers know which cars are good.
- Each good car is sold for $p \in [5, 6]$.
- Each bad car is sold for $p \in [2, 3]$.
- Each lemon is sold for $p = 0$, or unsold.
- The market of value clears.

Market with lemons: Expectations

Asymmetric information

- Only the sellers can tell the cars apart.
- Like before, the buyers settle on the expectation

$$\text{cars for sale} \quad = \quad \frac{1}{3} \cdot \text{good} + \frac{1}{3} \cdot \text{bad} + \frac{1}{3} \cdot \text{lemons}$$

  and they are willing to pay per car

$$p_1^* \quad = \quad \frac{1}{3} \cdot 6 + \frac{1}{3} \cdot 3 \ = \ 3$$

- Since $p_1^* < 5$, the good cars are withdrawn.

Market with lemons: Expectations

Asymmetric information

- Only the sellers can tell the cars apart.
- Like before, the buyers settle on the expectation

$$\text{cars for sale} \quad = \quad \frac{1}{2} \cdot \text{bad} + \frac{1}{2} \cdot \text{lemons}$$

so that the buyers are willing to pay per car

$$p_2^* \quad = \quad \frac{1}{2} \cdot 3 \; = \; \frac{3}{2}$$

- Since $p_2^* < 2$, the bad cars are withdrawn.

Market with lemons: Expectations

Asymmetric information

- Only the sellers can tell the cars apart.
- Like before, the buyers settle on the expectation

$$\text{cars for sale} \quad = \quad \text{lemons}$$

so that the buyers are willing to pay per car

$$p_3^* \quad = \quad 0$$

- The market collapses!

Solutions of information asymmetry

Information is provided in *authenticated signals*:

- certificates
- warranties
- reputation and feedback systems
- risk sharing
- …

Example

Collateralized debt obligations (CDOs)

- Mortgages are a risky investment for banks:
  - default risks: loss
  - prepayment risks: no profit
- CDOs are bundles of mortgages
  - risky mortgages are packaged with safe mortgages
  - the risks are averaged out

Example

Collateralized debt obligations (CDOs)

- Let a CDO $\mathscr{A}$ consist of
  - 100 mortgages
  - each worth 1M
  - default probability 10%
  - expected value of $\mathscr{A}$ is 90M

Example

Collateralized debt obligations (CDOs)

- Let a CDO $\mathscr{A}$ consist of
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Example

Collateralized debt obligations (CDOs)

- Let a CDO $\mathcal{A}$ consist of
  - 100 mortgages
  - each worth 1M
  - default probability 10% $\longleftarrow$ lemons
  - expected value of $\mathcal{A}$ is 90M

- Problem: assure the buyer that the risk is $\leq$ 10%

- Solution: seller keeps the risky part of $\mathcal{A}$
  - sell *senior tranche*: 85%
  - keep *junior tranche*: 15%
  - all defaults up to 15% go into the junior tranche

Market information security

- Market is an information processing plant
  - input: behaviors and utilities
  - output: prices

Market information security

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  - input: behaviors and utilities
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- Security requirements on the market
  - confidentiality: conceal private data (valuations. . .)
  - authenticity: prove public data (CDOs. . .)

Market information security

- Market is an information processing plant
  - input: behaviors and utilities
  - output: prices
- Security requirements on the market
  - confidentiality: conceal private data (valuations. . .)
  - authenticity: prove public data (CDOs. . .)
- Attacks on the market
  - against confidentiality and privacy: tracking, differential pricing. . .
  - against integrity and authenticity: spam, phishing, maladvertizing, booby-trapped CDOs. . .
  - **moral hazard, principal-agent problem|, rent-seeking**. . .
  - **fraud**: pyramid schemes, Libor rigging, malicious short selling. . .

Outline

Efficient Market Hypothesis

"Prices fully reflect all available information."

Eugene Fama

Efficient Market Hypothesis

Question

What is "all available information"?

Answer

- weak EMH: past prices
- semi-strong EMH: public information (past prices, news. . .)
- strong EMH: public and private information (valuations, strategies, inside information. . .)

Efficient Market Hypothesis

Question

What does it mean that "Prices reflect all available information"?

Answer (P. Samuelson)

It means that there are no arbitrage opportunities on the market, i.e. that the random variable

$$X = \text{expected return} - \text{predicted return}$$

- is unpredictable
- has the mean value 0

Efficient Market Hypothesis

Question

Why do prices reflect available information?

Answer

Otherwise, there would be arbitrage opportunities

- i.e., there would be successful gambles on X, based on additional information

Efficient Market Hypothesis

EMH on street

Eugene Fama is walking down the street with a friend. They come upon a $100 bill lying on the ground. The companion reaches down to pick it up, but Fama says: *"Don't bother. If it were a genuine $100 bill, someone would have already picked it up".*

Efficient Market Hypothesis

Social choice mechanisms

- market
- voting

Efficient Market Hypothesis

Social choice mechanisms

- Why do the bubbles happen?
- How long can the mass delusions persist?
- Does the truth always triumph in the end?