Information in networked world
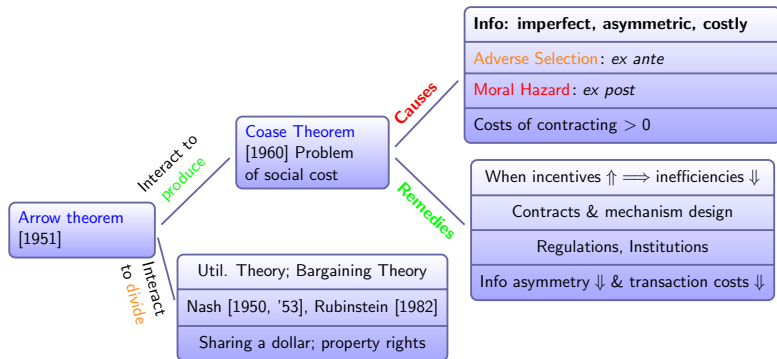
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Asymmetric Information
Adverse selection

Arrow impossibility theorem & its progenies I

We will make no distinction between TRANSACTION COSTS & CONTRACT COSTS

Today: Adverse Selection

- Lemon Market [Akerlof]
- Signalling [Spence]

Zoom on asymmetric info

Zoom on asymmetric info			
timing	Asymmetric info categories	Mechanisms of revelation	Examples
ex ante	Adverse selection [AS]	A signals to P to reveal hidden type (knowledge)	pre-existing condition (HIV virus / stuxnet) private info (network maintenance level)
ex post	Moral hazard [MH]	P designs contracts to induce desired A's action(s)	care to avoid theft effort / investment decision
ex ante ex post	Transaction costs	AS MH + hidden knowledge	

Arrow ['85] hidden action

Means to reveal asymmetric info			
time	Asymmetric info	Usage	Examples
ex ante	Signaling	a tool for AS	education, skill
ex post	Screening	a tool for MH	warranty

Principal: offers a contract; Agent: Accepts or rejects
[GI], p. 183 - 184, Figure 7, Table 7
http://www.rasmusen.org/GI/chapters/pageproofs4th/chap-07.pdf

Connecting asymmetric info with contractual costs

Costly info & costly contracts	
Adverse selection [AS]	*ex ante*
Moral hazard [MH]	*ex post*
Contractual costs > 0	*ex ante, ex post*

From asymmetric info to costly info ($\approx$ costly contracting)

- Player 1 $=$ less informed player
- Player 2 $=$ more informed player (has *hidden / private* info)
- Let player 1 *pay* (to an outside party) for player 2 private info $\implies$
  Asymmetric info $=$ perfect info, but contracting is costly

Reverse? from costly contracts to asymmetric info?

Connecting costly contracts with asymmetric info

From costly contracts to asymmetric info?

- Examples (no info asymmetry, but costly enforcement)
  1. Your bike: stolen by your neighbor
     the theft is known $\Longleftrightarrow$ no asymmetric info
  2. Technology: stolen & replicated; the theft produces counterfeit goods
     the theft is known $\Longleftrightarrow$ no asymmetric info

- In both examples = costly to prove / enforce good behavior
- If symmetric info, but unverifiable in court $\approx$ asymmetric info

Q: Is asymmetric info $\approx$ costly contracting?
A: Costly contracts & asymmetric info are surprisingly closely related.
In fact, economists view such environments as practically identical.

Principal-Agent paradigm: CPS applications

Example 1

- P: CPS manager for electric distributor
- A: Co that supplies & supports smart meters

Example 2

- P: Transportation: CalTrans
- A: Co that supplies & manages sensor network

Example 3

- P: Regulatory authority / Industry consortium
- A: CPS managers responsible for security choices

Akerlof'70: Lemon Market: seller type is hidden knowledge

$n + m$	# of players	$n \geq 2, m \geq 1$
I	a finite set of agents (sellers), $i \in I$	$I = \{1, ..., i, ..., n\}$
J	a finite set of principals (buyers), $j \in J$	$J = \{1, ..., j, ..., m\}$
t	seller types (or $\{\theta_i\}_{i=1}^{I}$)	$t = \{H, L\}; (\text{or } \theta_i \in \Theta_i)$
λ	a fraction of L-type agents	(known prob. dist.)
w^t	value of type t car for a buyer	$w^H > w^L$
u^i	utility function of i	$u^i \in \mathbb{R}_+^1$
e^i	characteristic of i	$e^i = (u^i, w^i)$
v^i	seller reservation value $v^{\max} := \max_i v^i$	$v^{\max} \in (w^L, w^H)$
v^i	$v^H < w^H$ and $v^L < w^L$	
π^j	profit of j	$\pi^j \in \mathbb{R}_+^1$
e^j	characteristic of j	$e^j = (\pi^j, v^j)$
E^i	a set of admissible characteristics for i	$e^i \in E^i$
$e \in E$	a pure exchange economy	$e = (e^1, \ldots, e^{n+m})$
E	a space of all possible economies	$E = \Pi_{i \in I, j \in J} E^i x E^j$
p^t	a (market) price of type t car	

Buyers are identical; risk neutral, and seller type is hidden.

Akerlof'70: Lemon Market: full info benchmark I

No hidden knowledge: perfectly observable seller types (H or L)

Then, prices differ with type: $p^L \neq p^H$. From [IR] constraints:

$$u^t = p^t - v^t \geq 0 \quad and \quad \pi = w^t - p^t \geq 0$$

we have:

$$v^L \leq p^L \leq w^L \quad and \quad v^H \leq p^H \leq w^H$$

Depending on price(s) formation (surplus sharing between sellers and buyers or demand-supply equilibrium), from standard economic analysis, market clearing prices p^L and p^H exist.

Akerlof'70: Lemon Market: a solution

Due to hidden knowledge $p^L = p^H = p$. From [IR] constraints:

$$u^t = p - v^t \geq 0 \quad and \quad \pi = w^j - p \geq 0$$

From buyer's and type H seller's [IR] resp. we have:

$$p \leq \bar{w} \quad and \quad p \leq v^H$$

or

$$v^H \leq p \leq \bar{w},$$

where $\bar{w} = \lambda w^L + (1 - \lambda) w^H$ is buyer's expect car value (on average).
But if λ is high enough, i.e., $\bar{w} < v^H$ no p exists for [IR]s to hold.

$$\bar{w} < v^H \Longleftrightarrow \text{lemon market} \Longleftrightarrow \text{missing market}$$

Type H does not trade. $\Longleftrightarrow$ missing market.

Akerlof'70: Lemon Market: formalization I

Theorem

For any game $G(N, M, E, \lambda)$ there exists $\lambda^* < 1$, such that for any $\lambda \in (\lambda^*, 1]$ type H market is missing. Only type L trades.

A generalization

Bayesian approach (following F&T notation) [p. 215]. Types are drawn from some objective (or subjective) prob. distribution $p(\theta) = p(\theta_1, ..., \theta_I)$.

Then $\bar{w} = \displaystyle\int_\Theta w(\theta) p(d\theta)$

Spence'73 Job Market: education = costly signal

$n + m$	# of players	$n \geq 2, m \geq 1$
I	a finite set of agents (students), $i \in I$	$I = \{1, ..., i, ..., n\}$
J	a finite set of principals (employers), $j \in J$	$J = \{1, ..., j, ..., m\}$
t	student types (or $\{\theta_i\}_{i=1}^I$)	$t = \{H, L\}$; (or $\theta_i \in \Theta_i$)
λ	a fraction of L-type agents	(or any known prob. dist.)
w^i	type t productivity for the employer	$w^H > w^L$
s^i	education: a choice variable; costly	$s^i \in \mathbb{R}_+^1, w^i(s) = \text{const}$
u^i	utility function of i	$u^i \in \mathbb{R}_+^1$
$e^{i/j}$	characteristic of i/j	$e^i = (u^i, t, s^i); e^j = (\pi^j)$
v^i	student's reservation wage $v^{\max} := \max_i v^i$	$v^{\max} \in (w^L, w^H)$
v^i	$v^H < w^H$ and $v^L < w^L$	
π^j	profit of j	$\pi^j \in \mathbb{R}_+^1$
$E^{i/j}$	a set of admissible characteristics for i/j	$e^i \in E^{i/j}$
$e \in E$	exchange economy	$e = (e^1, ..., e^{n+m})$
E	a space of all possible economies	$E = \Pi_{i \in I, j \in J} E^i \times E^j$
ω	market wage	(price of labor)

Employers are identical; risk neutral, and student's type is hidden.

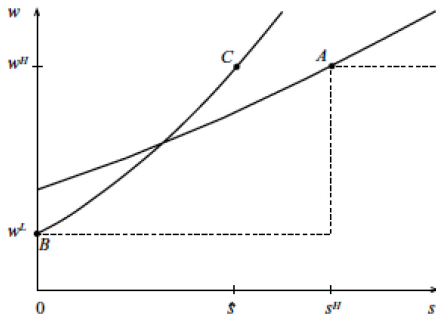# Spence'73 Job Market: solution requires single crossing I

Fig. 1. Indifference curve for low-productivity job applicants (steep) and indifference curve for high-productivity job applicants (flat)

- with no signal $\rightarrow$ back to Akerlof'70
- with a signal (education): separating eq. $(s = 0, w^L); (s = \hat{s}, w^H)$

Akerlof'70: Lemon Market

Lemon Market = Missing Market

It is hard (or impossible) to buy a cheap (and reliable) used car. Sellers with good cars (type H do not sell them – market price is too low due to lemons. [Sellers with type H cars prefer to donate.]

Is it a trivial result?

Yes, but only after it was discovered. $\iff$ No, it is not a trivial result.

On Impossibility of Informationally Efficient Markets

Grossman-Stiglitz'80 Impossibility $=$ Interior Optimum

Is it a trivial result?
Yes, but only after it was discovered. $\iff$ No, it is not a trivial result.

Mechanism design via contracts I

Incomplete contracting = surplus sharing between P & A

- Bargaining: dividing a surplus (dollar / pie) [fixed size]
- Incomplete contracting: dividing a surplus [variable size]

Incomplete Contracting = generalized bargaining

Contract theory jargon

- Property rights = the rules of dividing surplus between players
- Agency problem, incomplete contacts, principal-agent problem: Allocating property rights for endogenous (variable) surplus under info asymmetries:
    - hidden information
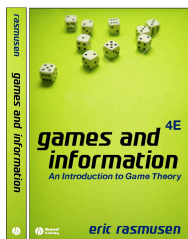   - hidden actions

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