

Pricing unverifiable information

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Big picture

Premise: Seller and buyer have agreed to trade specific information.

- We remain mostly agnostic on exact mechanism.
- We have in mind information structures.
 - Examples: credit rating agencies (information traded by itself); credence goods (information bundled with subsequent action)
 - Main feature: information is unverifiable.

General problem: How is the seller compensated?

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Place in the literature

- Part of surging literature on **markets for information** (overview by Bergemann & Bonatti (2019))
- Related to the “mechanism design approach”: Babaioff, Kleinberg & Paes Leme (2012); Bergemann, Bonatti & Smolin (2018); Esö & Szentes (2008); Hörner and Skrzypacz (2016); ...
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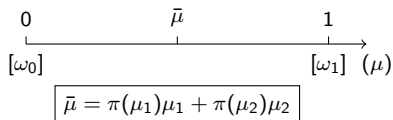
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Preliminaries

INFORMATION STRUCTURES/(BAYESIAN) SIGNALS:

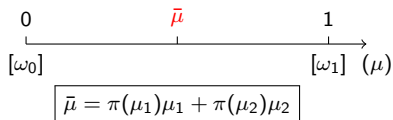
- (Binary) **state space**: $\Omega = \{\omega_0, \omega_1\}$
- (Common) prior belief (of ω_1 occurring): $\bar{\mu} \in (0, 1)$
- Signal (mean-preserving distribution): $\pi \in \Delta([0, 1])$



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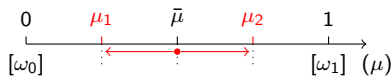
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$$\bar{\mu} = \pi(\mu_1)\mu_1 + \pi(\mu_2)\mu_2$$

Overview

- (Risk-neutral) buyer and seller agree that **seller will acquire specific signal** and report the realized posterior to the buyer.
- Buyer cannot verify either signal or realized posterior

Solution: Replace verifiability with incentive-compatibility

- Together with the signal, they agree that seller is compensated with menu of (state-contingent) acts.
- Seller acquires signal and chooses an action from the menu.

Ideally: Desired signal is uniquely optimal and action reveals posterior

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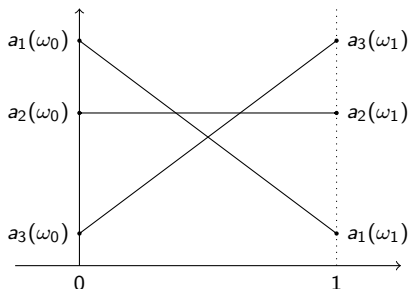
Menus of acts

- Menu (satisfying no-liability): $A = \{a_1, a_2, a_3\} \subseteq \mathbb{R}_+^\Omega$
- (Optimal) expected payoff:

$$\phi_A(\mu) = \max_{a \in A} \mathbb{E}_\mu(a)$$

- Expected payoff of a signal:

$$\mathbb{E}_\pi(\phi_A) = \pi(\mu_1)\phi_A(\mu_1) + \pi(\mu_2)\phi_A(\mu_2)$$



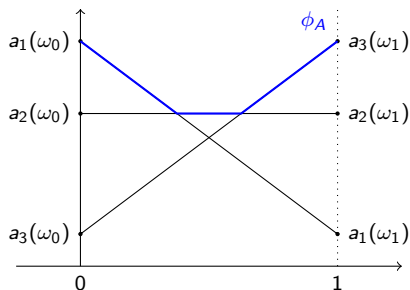
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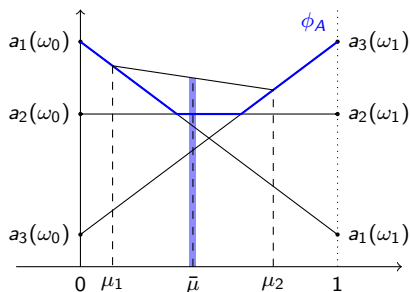
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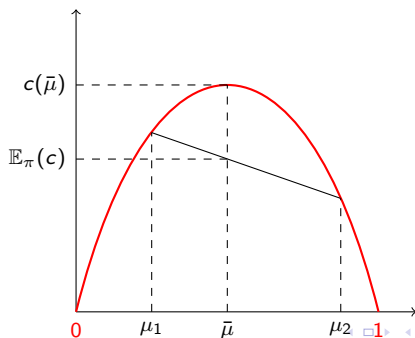


Cost of information

- **Information is costly** to acquire (for the seller): $C(\pi) \geq 0$
- Posterior separability:

There is strictly concave $c : [0, 1] \rightarrow \mathbb{R}$ s.t. $C(\pi) = c(\bar{\mu}) - \mathbb{E}_\pi(c)$

- Generalizes usual Shannon entropy specification ($c = \lambda H$)
- Common specification for processing information
- Theoretical foundations (...) / empirical evidence (Dean & Neligh, 2019)

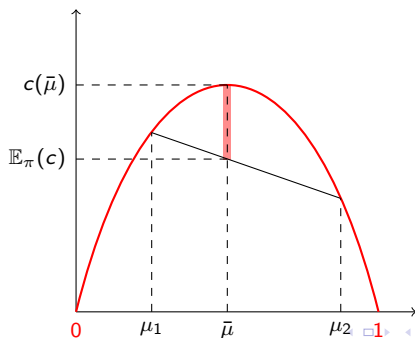


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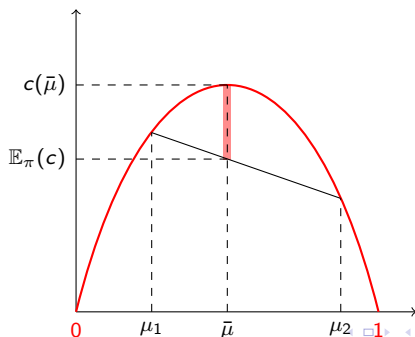


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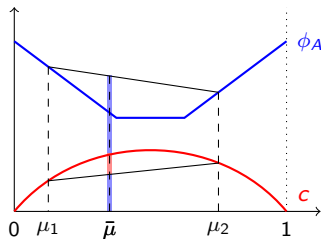


Seller's optimal signal: Concavification

- **Seller's surplus:** $\mathbb{E}_\pi(\phi_A) - C(\pi)$
- Seller's optimal signals (given menu A):

$$\begin{aligned}\Pi_A &= \arg \max(\mathbb{E}_\pi(\phi_A) - C(\pi)) \\ &= \arg \max(\mathbb{E}_\pi(\phi_A) - c(\bar{\mu}) + \mathbb{E}_\pi(c)) \\ &= \arg \max(\mathbb{E}_\pi(\phi_A + c))\end{aligned}$$

- Take the concave closure of $\phi_A + c$ (Aumann & Maschler, 1995)
- Find posteriors in the support of optimal signals

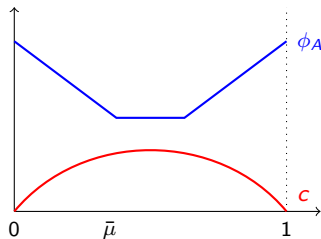


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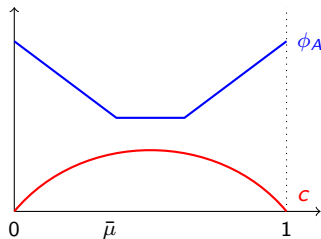


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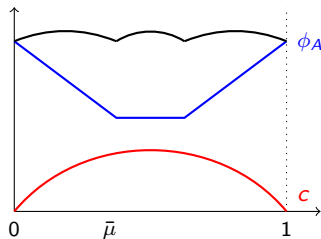
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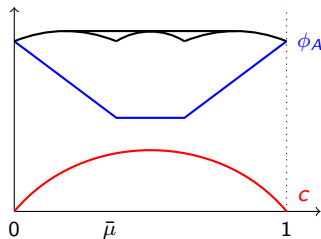
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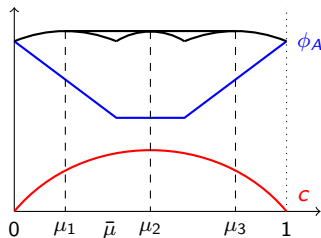
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First Research Question

Can we guarantee the desired signal will be chosen?

Guaranteeing the desired signal

Theorem

A signal can be guaranteed if and only if it is binary:

There exists menu A such that $\Pi_A = \{\pi\}$ if and only if $|\text{supp}(\pi)| = 2$.

- **NECESSITY:** If the signal is not binary, there are multiple ways to optimally combine the posteriors (see previous slide).
- **SUFFICIENCY:** We can do even better, viz., characterize the menus that guarantee the optimal signal (see next slide)!!!

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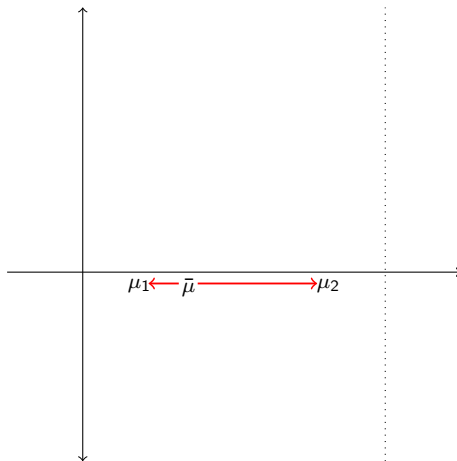
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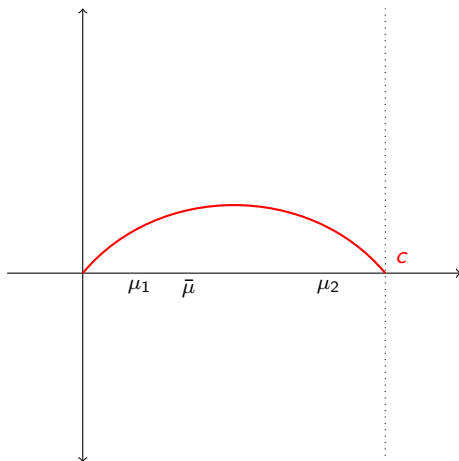
Menu that guarantee binary signal

Construction of menu that guarantees **desired signal**



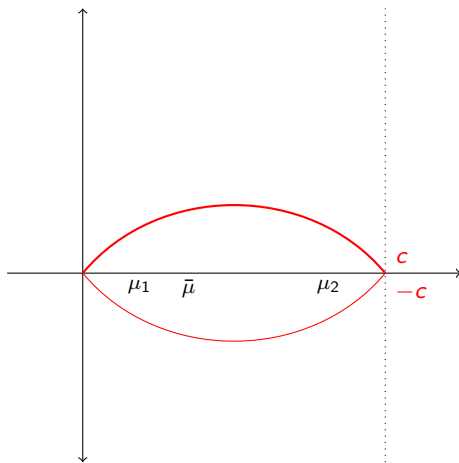
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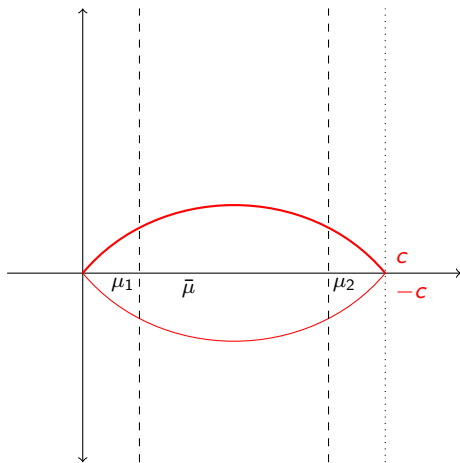
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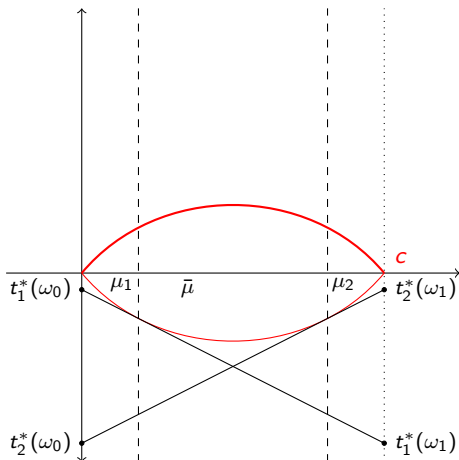
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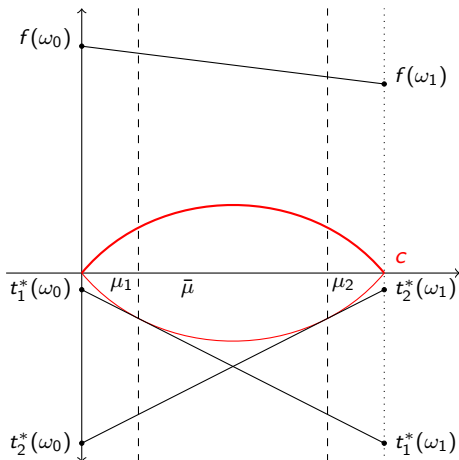
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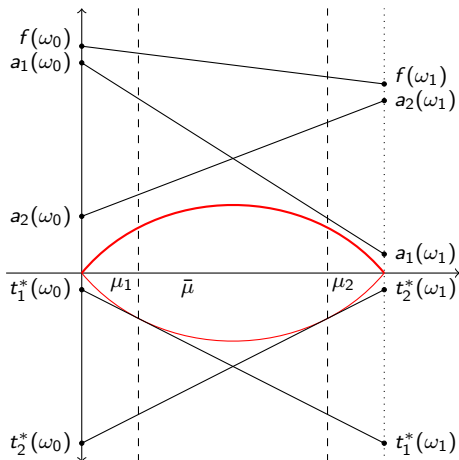
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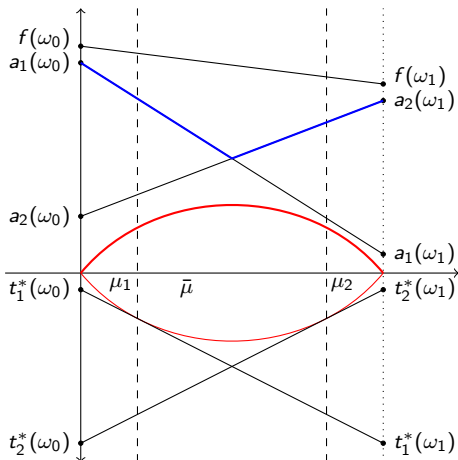
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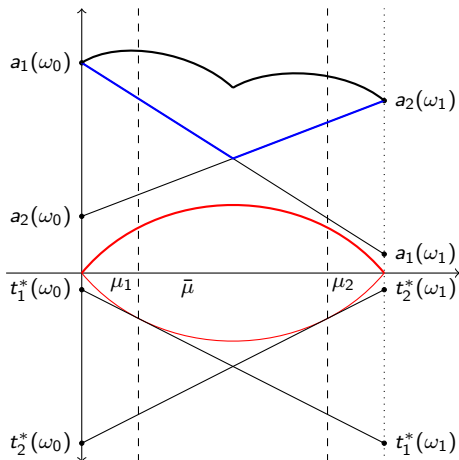
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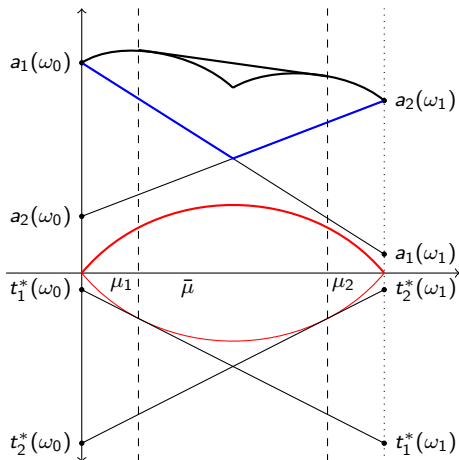
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Characterizing menus that guarantee binary signal

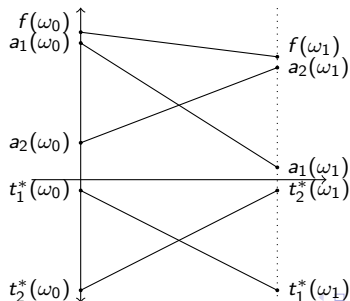
Theorem

A menu guarantees the signal iff it is constructed as in previous slide:

$\Pi_A = \{\pi\}$ if and only if $A = \{t_1^* + f, t_2^* + f\}$ for some $f \in \mathbb{R}^\Omega$.

DECOMPOSITION OF OPTIMAL MENU INTO:

- Variable payment: depends on (implicitly) reported posterior
- Flat payment: does not depend on (implicitly) reported posterior



Characterizing menus that guarantee binary signal

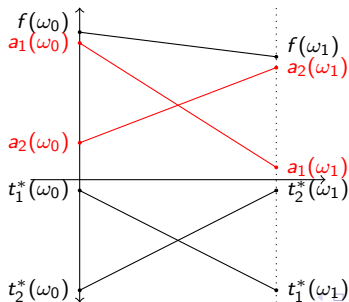
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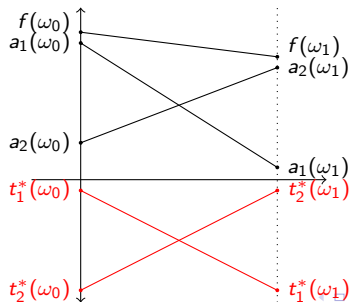
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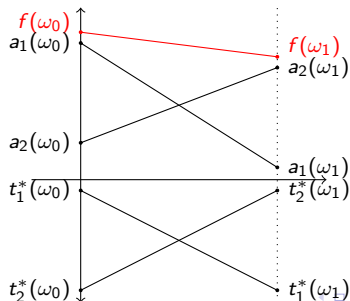
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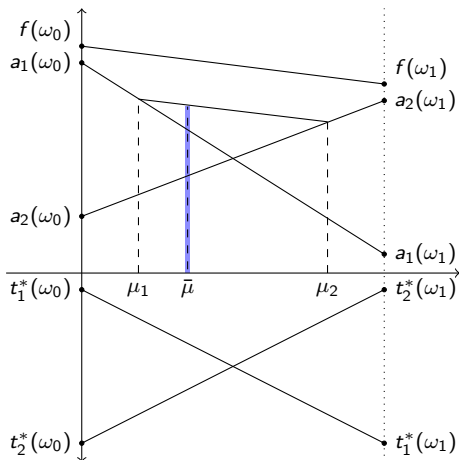


Second Research Question

How much does the desired signal cost (in expectation)?

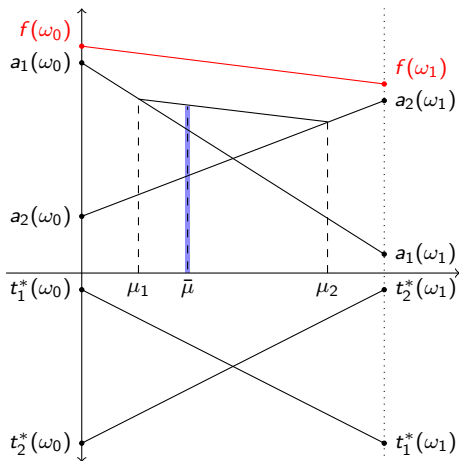
(Expected) price of a menu that guarantees a signal

- Expected price for π : $\mathbb{E}_\pi(\phi_A)$
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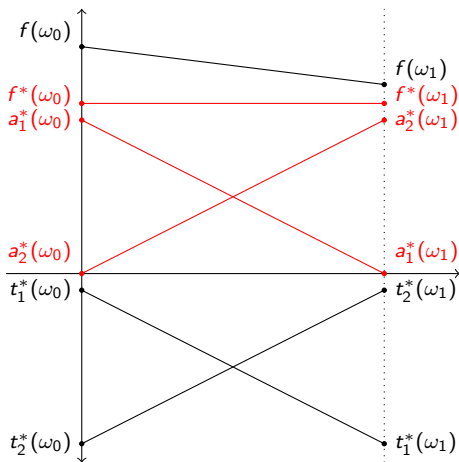
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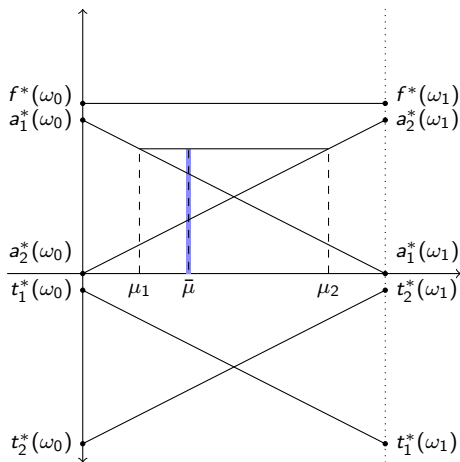
Cheapest price of a menu that guarantees a signal

- Make f as cheap as possible to satisfy the no-liability condition.
- Cheapest expected price: $K(\pi)$.



Cheapest price of a menu that guarantees a signal

- Make f as cheap as possible to satisfy the no-liability condition.
- **Cheapest expected price:** $K(\pi)$.



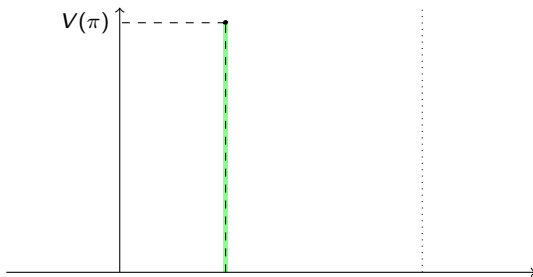
Main Research Question

How is the surplus split between the seller and the buyer?

Splitting the surplus

- **Value of a signal:** $V(\pi) > K(\pi)$
- Total (expected) surplus:

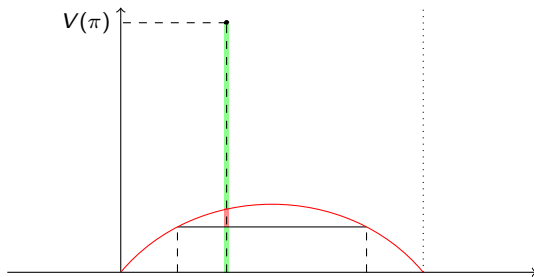
$$\begin{aligned}
 S(\pi) &= V(\pi) - C(\pi) \\
 &= \underbrace{(V(\pi) - \mathbb{E}_\pi(\phi_A))}_{\text{Buyer's surplus}} + \underbrace{(\mathbb{E}_\pi(\phi_A) - C(\pi))}_{\text{Seller's surplus}}
 \end{aligned}$$



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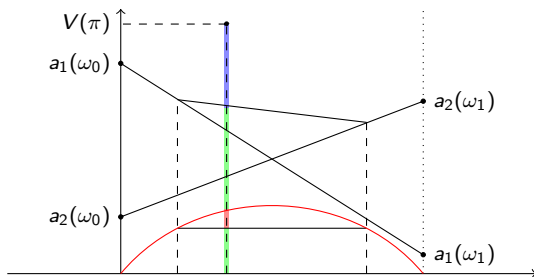
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Guaranteed seller's surplus

Theorem (Main result)

The seller is guaranteed to receive strictly positive (expected) surplus.
Formally, $K(\pi) > C(\pi)$.

The result holds in a very broad range of settings.

- No matter how unfavorable things are for the seller, e.g., even if
 - buyer has all the bargaining power
 - seller is completely uninformed of buyer's preferences
 - buyer knows seller's preferences
- The result holds irrespective of market mechanism, e.g.,
 - the agents engage in bargaining
 - there is competition among sellers

Message: Seller always overpaid due to unverifiability of information

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Questions???