Reselling Information

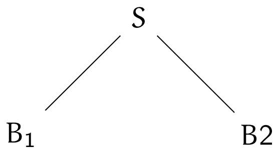
S. Nageeb Ali, Ayal Chen-Zion, & Erik Lillethun

Penn State, Amazon, & Colgate

July 24, 2020

What is the impact of resale on the price of information?

benchmark: vanilla world without resale



Seller has information (e.g., knowledge of ω).

Buyer's value for information $= 1$; payoff of 0 until then.

Each link meets with probability $\lambda\,\mathrm{d}t$ in period of length $\mathrm{d}t$.

Each player discounts future at rate $r > 0$.

Frequency of interaction per unit of *effective time* is λ/r.

Each buyer obtains info only from the seller.

Equilibrium = Nash Bargaining + Rational Expectations.

So an equilibrium price p solves

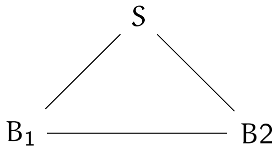
$$\underbrace{p - p\int_0^\infty e^{-rt}e^{-\lambda t}\lambda\,dt}_{\text{Seller's Gain from Selling Today}} = \underbrace{(1-p) - (1-p)\int_0^\infty e^{-rt}e^{-\lambda t}\lambda\,dt}_{\text{Buyer's Gain from Buying Today}}.$$

$\implies p = \frac{1}{2}$.

Without resale, buyers and seller split the surplus.

Seller's payoff $\to \frac{1}{2}\times$ social surplus as $\lambda/r \to \infty$

pricing with resale



Once a buyer obtains info, he can sell it to the other buyer at the next trading opportunity.

Key idea: information is replicable ⇒ buyer can both consume and sell it.

pricing with resale

Sale of information is publicly observed.

Payoff-relevant state is the set of informed players:

$$s \in \Big\{\{S\}, \{S, B_1\}, \{S, B_2\}, \{S, B_1, B_2\}\Big\}.$$

Equilibrium $\equiv$ value functions $V_i(s)$ and prices $p_{ij}(s)$ where

1. Value functions satisfy *rational expectations* given prices,
2. Prices satisfy *symmetric Nash bargaining* given value functions:
   - Trade today iff trading today increases bilateral surplus.
   - prices split the gains from trade equally.

Study both *immediate agreement* and *seller's optimal* equilibria.

$$s = (S, B_1)$$

Proceed by backward induction: suppose S and B_1 have information.

B_2 can buy information from either S or B_1: 2 trading partners.

Prices $p_{S2}(s) = p_{12}(s)$ and solve

$$\underbrace{p - p\int_0^\infty e^{-rt}e^{-2\lambda t}\lambda\,dt}_{\text{Seller's Gain from Trading Today}} = \underbrace{(1-p) - (1-p)\int_0^\infty e^{-rt}e^{-2\lambda t}2\lambda\,dt}_{\text{Buyer's Gain from Trading Today}}.$$

$$\implies p(2) = \frac{r}{2r+\lambda},$$

which converges to 0 in a frictionless market ($\lambda/r \to \infty$).

key idea

For buyer, gain from trading today is cost of delay ≈ 0.

For a seller, gain from trading today $>> 0$ because she may lose buyer to other seller.

Equating these two gains implies prices must vanish.

Is this intuitive?

- Yes: Bertrand outcome expected if B_2 met S and B_1 simultaneously.
- No: B_2 meets only one at a time, faces costs from delay, and so *Diamond Paradox* may apply.

Slight bargaining power to the buyer averts the Diamond Paradox.

two uninformed buyers remain

Let $\gamma \equiv \int_0^\infty e^{-rt} e^{-2\lambda t} \lambda \, dt$, which converges to $\frac{1}{2}$ as $\lambda / r \to \infty$.

Suppose S meets a buyer.

Buyer's payoff:

- Trading today: $1 - p(1) + \gamma p(2) \to 1 - p(1)$.
- Waiting: $\gamma(1 - p(1) + \gamma p(2)) + \gamma(2\gamma)(1 - p(2)) \to 1 - \frac{p(1)}{2}$.

The payoff from waiting is higher if $p(1) > 0$.

Therefore, $p(1) \to 0$ as $\lambda / r \to \infty$.

discussion

The seller is a *monopolist* on information.

But neither he nor the first buyer cannot commit to selling information to the second buyer.

$\Longrightarrow$ the second buyer gets information for virtually free.

Little incentive for the first buyer to pay a lot for info:

- Resale price is low.
- Waiting to be the second buyer involves minimal delay.

seller-optimal equilibrium

The seller-optimal equilibrium may involve delayed agreements.

Structure of equilibrium:

- Seller never sells info to B_2 before she sells info to B_1.
- Once seller sells info to B_1, then both compete to sell it to B_2.

In this equilibrium, every meeting between S and B_2 has no trade before B_1 is informed.

$\Rightarrow$ B_1 knows that he is always first buyer and so he pays $\frac{1}{2}$.

not-trading must be credible

Is it credible for S and B_2 to not trade?

$$\underbrace{\frac{\lambda}{r+\lambda}\left(\frac{1}{2}+\gamma p(2)\right)}_{\text{Seller's cont value}}+\underbrace{\frac{\lambda}{r+\lambda}\left(2\gamma(1-p(2))\right)}_{\text{Buyer's cont value}}>\underbrace{1+2\gamma p(2)}_{\text{Joint Surplus with Trade}}.$$

whenever $\lambda/r > 5$.

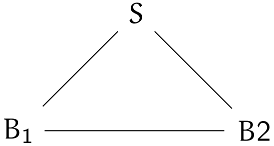
Seller-optimal equilibrium features delay.

Seller obtains bilateral bargaining price from at most 1 buyer in any equilibrium.

Clearly, seller can do better if she can prohibit resale. But are there any non-contractual solutions?

what if information weren't replicable?

an interlude



Suppose the good were non-replicable:

- There is only a single copy of the good, of value 1 to each buyer.
- A buyer who possesses it can consume or re-sell it.

Led Zeppelin, Past, Present and Future

Once a buyer obtains the good, there is no reason to re-trade.

Equilibrium prices solve

$$\underbrace{p(1-2\gamma)}_{\text{Seller's Gain from Trading Today}} = \underbrace{(1-p)\gamma}_{\text{Buyer's Gain from Trading Today}}.$$

Recall that $\gamma = \int_0^\infty e^{-rt}e^{-2\lambda t}\lambda\,dt \to \frac{1}{2}$.

$\Rightarrow$ seller obtains the entire social surplus.

the seed of a solution: a prepay scheme

What if seller could *sell* the right to be the 2nd buyer?

She first sells a single token to either buyer.

If buyer B_i buys that token, then the seller always sells info first to the other buyer. Token confers the right to be the 2nd buyer of info, who buys info at ≈ 0.

- Value of token $= p(1) - p(2) \approx 1/2$.
- Fewer tokens than buyers $\Rightarrow$ Seller captures full value of token.
- Seller obtains $\approx 1/2$ for the token and $\approx 1/2$ for info!

Seller obtains value of intellectual property protection without any commitment or IP regulation!

Value from purchasing token is V_t and price of token is p_t.

$$V_t = -p_t + \frac{\lambda}{r+\lambda}(2\gamma)(1-p(2)) \to 1 - p_t \text{ as } r \to 0.$$

Seller's Gain from Selling Token = Buyer's Gain from Buying Token

$$\frac{r}{r+\lambda}\left(p_t + \frac{\lambda}{r+\lambda}p(1) + \gamma p(2)\right) = V_t - \gamma V_t - \frac{\gamma\lambda}{r+\lambda}(1-p(1)+\gamma p(2))$$

Taking limits as $r \to 0$,

$$0 = \frac{1-p_t}{2} - \frac{1-p(1)}{2} \implies p_t \to p(1) = 1/2$$

prepay scheme

Tokens play the role of encoding a minimal degree of history dependence:

- Tokens need not be "physical."
- Scheme exploits competitive forces + resale.
- Buyer pays so much for token because he buys info for ≈ 0 later.

Could also implement solution by slicing / encrypting information into different bits, and selling each bit separately.

General model allows for a general set of buyers and sellers, all connected by a complete graph.

Bargaining weights need not be symmetric across trading roles, but seller doesn't have full bargaining power.

Paper shows that price of info $\to 0$ as soon as two players have information.

- $\Rightarrow$ In a MPE, only way for seller to obtain surplus is if she is a monopolist, and to do so from the first buyer.
- $\Rightarrow$ If seller is a monopolist, she can obtain the full IP value of her information using a token scheme where she sells $n-1$ tokens before selling information.

wrap up

Clearly relevant for thinking about trading for information, incentives to acquire expertise, etc.

- Information is non-rivalrous in consumption.
- But a market for information can exclude others.

Commitment problems $\rightarrow$ difficulty in appropriating surplus from info.

But commitment problem can be exploited to solve the resale problem.

related literature

Hinting at problem: Arrow (1962).

Verifiability Problem: Anton & Yao (1994); Horner & Skrzypacz (2014).

Resale problem: Polanski (2007, 2019), Manea (2020).

Intermediation / bargaining: Condorelli, Galeotti, & Renou (2016), Manea (2018), Elliot & Talamas (2019).

Thank you.