Price Discrimination and Social Networks – Use of Social Networks as a Tool for Mitigating Asymmetric Information Problems

work in progress

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Information Problems and Social Networks

- Some studies show that markets where information problems or/and uncertainty arise tend to be “networked”, and some studies propose that use of social networks can mitigate adverse selection and moral hazard problems, but this area is still under-developed
  - Some examples: job-seeking, micro-finance groups, online peer-to-peer lending groups, price discrimination.
- We did not find theoretical models underlying this issue
- What we made: a theoretical modeling
- Only a first draft – work in progress
  - We use the case of price discrimination as an illustration in this paper, but we are working on other cases (micro-finance groups, job-seeking) as well.
  - The conclusions we draw can be generalized and can be applied to several situation where asymmetric information appears and social network has important role

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Price Discrimination and Homophily

- Several studies show that education (Schneider et al 1997), occupation and social class (Wright 1997) can be one source of homophily in social networks
  - (a good overview of research on homophily: McPherson, Smith-Lovin and Cook (2001)).
- Thus we can assume that social ties of various types of buyers show some degree of homophily
  - Willingness to pay is related to the socio-economic characteristics of the buyers (their financial situation, income, savings and some other features)
- Building upon the homophily emerging in buyers' social ties we developed a model of price discrimination.
- In this application we examine how the social network can be used to mitigate asymmetric information problems (adverse selection) what characterize these transactions
- We apply a basic principal-agent model based on Laffont and Martimort (2002) to describe price discrimination under asymmetric information, where the social structure is grabbed by probability distribution of ties.

The Model: Assumptions – The Firm

- Only one firm sells a product with no close substitutes
- The firm produces a single product at constant marginal cost (*c*).
- The company uses nonlinear pricing, it designs menus
  - each consisting of a quantity (or quality) package of the good and a total payment for this quantity (quality) package.

$$\mathcal{A} = \{(q, t)\} \qquad q \in R_+, t \in R_+$$

- The firm's profit (on each buyers):

$$\pi(q_i, t_i) = t_i - c(q_i)$$

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The Model: Assumptions – Buyers

- The buyers vary in their reservation price or willingness to pay
- There are only two different types of customer on the market:
  - high willingness to pay – low willingness to pay.
- The buyer's utility function:

$$U_i(q_i, t_i) = \theta_i u(q_i) - t_i \quad (i = l, h)$$

  - θ_i measures the difference of their willingness to pay
  - θ belongs to the set $\Theta = \{\theta_l, \theta_h\}$, where $\theta_l < \theta_h$ (so the same quantity q is evaluated higher by a buyer with high willingness to pay than by a low valuation type)
- Buyers can have either low valuation (θ_l) with probability ν or high valuation (θ_h) with probability $1 - \nu$

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The Model: Assumptions – Social Structure

- Each type of buyers can form social ties with both same types and other types,
- but homophilous behavior characterizes them,
  - each valuation type of buyers tend to form more same-type ties and fewer other-type ties (the probabilities of forming same-type and other-type ties are different)

We defined the following probalities:

- if a high willingness-to-pay consumer “meets” a same-type person, the probability of forming a social tie between them is η_{hh}
  - and with a low valuation person: η_{hl}
  - where $\eta_{hh} > \eta_{hl}$ (due to the homophily)
- Since the probability of picking a high valuation type from our simple two-type “society” is $1 - \nu$, the final probability of forming a same-type social tie by a high willingness-to-pay consumer is $(1 - \nu)\eta_{hh}$
- The probabilities of forming ties by a low willingness-to-pay costumer can be similarly deduced: $\nu\eta_{ll}$ and $\nu\eta_{lh}$

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The Model: Assumptions – Social Structure

For simplicity, we introduce two assumptions

- The probabilities of forming same-type ties are the same: $\eta_{hh} = \eta_{ll} = \eta_{same}$
  - and the probabilities of forming other-type ties are also equals: $\eta_{hl} = \eta_{lh} = \eta_{diff}$.
- Second, let us assume that $\eta_{same} = 1 - \eta_{diff} > \frac{1}{2}$

Thus, the final probabilities are more transparent:

- forming a same-type social tie by a high willingness-to-pay consumer is $(1 - \nu)\eta$
- forming a same-type social tie by a low willingness-to-pay consumer is $\nu\eta$
- forming an other-type social tie by a high willingness-to-pay consumer is $(1 - \nu)(1 - \eta)$
- forming an other-type social tie by a low willingness-to-pay consumer is $\nu(1 - \eta)$
  - where $\eta > \frac{1}{2}$ (due to the homophily)

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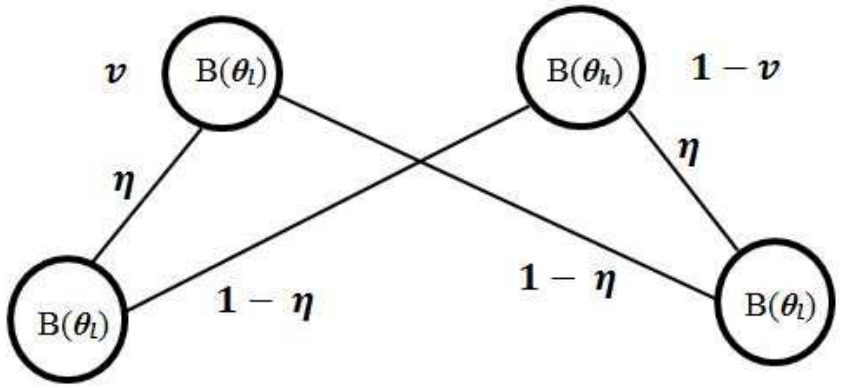
Social Structure – Structure of Probabilities



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The Model: Assumptions – Information Structure and Timing

- The firm cannot observe the type (willingness to pay) of each buyers.
  - (buyers can have either low valuation (θ_l) or high valuation (θ_h) with respective probabilities ν and $1-\nu$),
- The probability distribution of types is *common knowledge.*
- The firm moves first (it offers a contract menu) anticipating the buyers' subsequent behavior and optimizing accordingly within the set of available contracts.
- But before optimizing the contract menu the firm has the chance to discover some of its former buyers' social ties, whose type became unraveled in former transactions
  - e.g. by using social media or by the former buyers' referrals (by a referral program).
- Thus the firm has the opportunity to use this information during optimization of nonlinear pricing menu.

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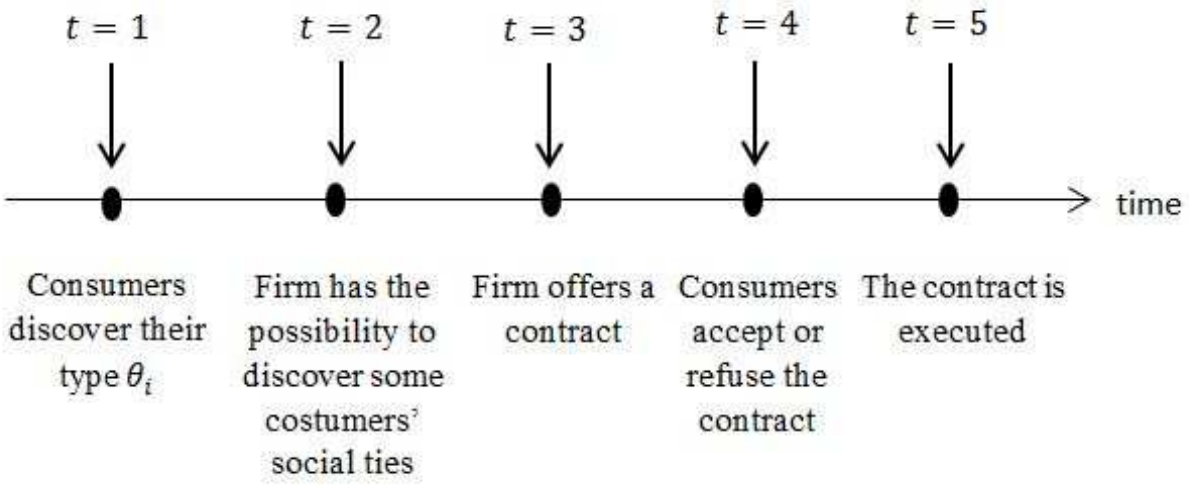
Timing



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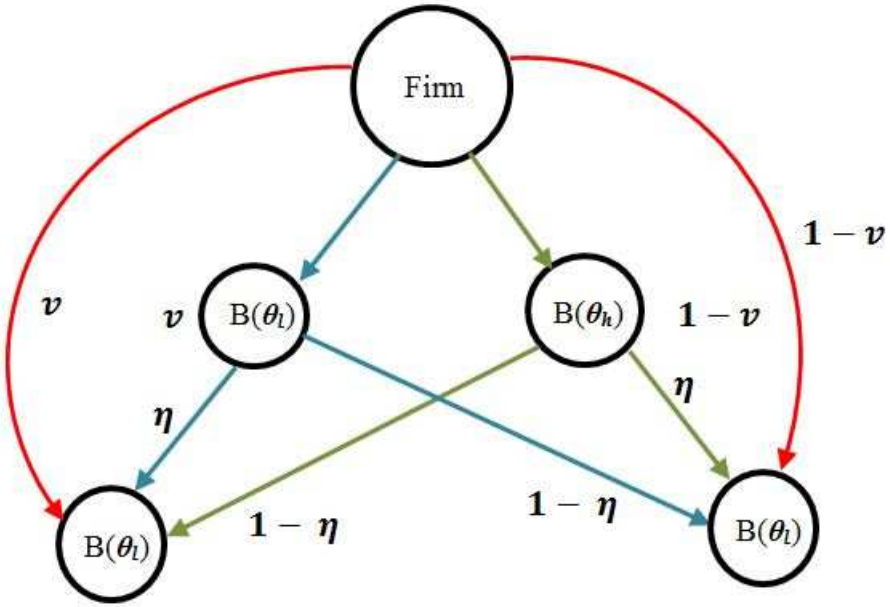
The Model: Assumptions – Information Structure (Probability Distribution)

- Since the firm knows only the probability distribution, it is a Bayesian expected utility maximizer.
- The optimal menus offered to various types of buyers depend on the probability distribution.
- If the firm knows high and/or low valuation consumers, it is able to revise the probability distribution by using the discovered consumers' social ties.
- The firm can „reach" each type of consumers on three ways with different probability distributions

3 Cases of „Reaching” Buyers



Discovered buyers

New buyers

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Probability Distribution: 3 Cases of „Reaching" Buyers

- Case A: if the firm does not have any information about a potential consumers' social network, the buyer's willingness to pay can be low with probability ν and it can be high with probability $1-\nu$.
- Case B: if the firm knows a low valuation consumers and it picks a potential consumer from the known low valuation buyer's social links, the new buyer's willingness to pay can be also low with probability $\frac{\nu\eta}{\nu\eta+(1-\nu)(1-\eta)}$ and it can be high with probability $1-\frac{\nu\eta}{\nu\eta+(1-\nu)(1-\eta)}$ (based on the "final" probabilities defined above).
- Case C: if the firm knows a high valuation consumers and it picks a potential consumer from the known high valuation buyer's social ties, the new buyer's willingness to pay can be also high with probability $\frac{(1-\nu)\eta}{(1-\nu)\eta+\nu(1-\eta)}$ and it can be low with probability $1-\frac{(1-\nu)\eta}{(1-\nu)\eta+\nu(1-\eta)}$

Notice that

- the probabilities we got in case B and C actually are similar to the Homophily index, $H_i=\frac{s_i}{s_i+d_i}$
- if η is not informative, i.e., there is no homophily ($\eta=1-\eta=1/2$), the probabilities of each types will be the original ones in case B and C as well: ν and $1-\nu$.

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Constraints and Optimization Program of the Firm

- Based on the probability distributions, we can describe the firm's optimization program for one buyer in expected terms.
- The firm faces some constraints that we have to define
  - The incentive and participation constraints define the set of *incentive feasible allocations*
  - Buyers' utility functions ($U_l(q_l, t_l) = \theta u(q_l) - t_l$ and $U_h(q_h, t_h) = \theta u(q_h) - t_h$) can be translated as an information rent left at the different types of buyers

Participation constraints:

$$U_l \geq 0, \text{ that is } \theta_l u(q_l) - t_l \geq 0 \quad (IR_l)$$

$$U_h \geq 0, \text{ that is } \theta_h u(q_h) - t_h \geq 0 \quad (IR_h)$$

Incentive constraints:

$$U_l \geq U_h - \Delta\theta u(q_h), \text{ that is } \theta_l u(q_l) - t_l \geq \theta_l u(q_h) - t_h, \quad (IC_l)$$

$$U_h \geq U_l + \Delta\theta u(q_l), \text{ that is } \theta_h u(q_h) - t_h \geq \theta_h u(q_l) - t_l. \quad (IC_h)$$

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Constraints and Optimization Program of the Firm

- The firms' constrained optimization problem

$$E\pi(q_l, q_h, t_l, t_h) = p[t_l - c(q_l)] + (1-p)[t_h - c(q_h)]$$

subject to IR_l, IR_h, IC_l, IC_h

- From the first order conditions we get the following optimal conditions that set the profit-maximizing outputs

$$\theta_h u'(q_h) = c'(q_h) \text{ and } \theta_l u'(q_l) - \frac{1-p}{p}(\theta_h - \theta_l)\, u'(q_l) = c'(q_l)$$

  - the firm offers to the high valuation consumers the same quantity that it would offer in optimum without asymmetric information (i.e., when the firm could perfectly detect the valuation type of the buyers), but the low willingness-to-pay clients are provided less, than under perfect information.
- Using the profit-maximizing quantities we get the optimal tariffs:

$$t_l = \theta_l u(q_l), \text{ that is, } U_l = 0$$

$$t_h = \theta_h u(q_h) - (\theta_h - \theta_l)u(q_l), \text{ that is, } U_h = (\theta_h - \theta_l)u(q_l)$$

  - the high valuation customers can realize some information rent

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Optization in the 3 Cases

- The level of this information rent depends on the quantity offered to the low valuation type buyer
- There is an information rent-allocative efficiency trade-off. So this downward distortion is rewarding for the firm: the information rent of the high WTP buyers reduces along with the quantity offered to the “low type”.
- And the extent of downward output distortion of low valuation type depends on the probability distribution ($\frac{1-p}{p}$ in the optimal condition).
- This is what is important to us here: as the probability of encountering low valuation buyer decreases, it is rewarding to reduce the quantity offered to her, and then the information rent of the more likely high valuation type will also decrease.

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Optization in the 3 Cases: Probability Distributions and the Level of Downward Distortion

So the firm has to offer three different menus (with different q_l and t_h, t_l) to each types,,

- to the buyers whose social network is unknown (Case A): $\mathcal{A}^A = \{(q_l^A, t_l^A), (q_h^A, t_h^A)\}$
  - where $p_A = \nu$, so the downward distortion is $\frac{1-p_A}{p_A} = \frac{1-\nu}{\nu}$
- to the buyers in a former, unraveled low WTP buyer's social network (Case B): $\mathcal{A}^B = \{(q_l^B, t_l^B), (q_h^B, t_h^B)\}$
  - where $p_B = \frac{\nu\eta}{\nu\eta+(1-\nu)(1-\eta)}$, so the downward distortion is $\frac{1-p_B}{P_B} = \frac{\boldsymbol{(1-\nu)(1-\eta)}}{\boldsymbol{\nu\eta}}$
- to the buyers in a former, unraveled high WTP buyer's social network (Case C): $\mathcal{A}^C = \{(q_l^C, t_l^C), (q_h^C, t_h^C)\}$
  - where $p_C = \frac{(1-\nu)\eta}{(1-\nu)\eta+\nu(1-\eta)}$, so the downward distortion is $\frac{1-p_C}{P_C} = \frac{\boldsymbol{(1-\nu)\eta}}{\boldsymbol{\nu(1-\eta)}}$

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Optization in the 3 Cases

- Since the relations of probabilities of high WTP buyer in each cases (under homophily, i.e. $\eta > \frac{1}{2}$) are:

$$p_C = \frac{(1-v)\eta}{(1-v)\eta + v(1-\eta)} > p_A = 1 - v > p_B = 1 - \frac{v\eta}{v\eta + (1-v)(1-\eta)}$$

- Then in optimal menus from FOCs:

$$q_l^C < q_l^A < q_l^B,\ t_l^C < t_l^A < t_l^B \text{ and } t_h^C > t_h^A > t_h^B$$

- And this set of menus yields higher profit for the firm.

What we tried to present: social embeddedness of buyers can be used as a screening tool to mitigate the information problem.

We could show in a formalized model that building upon the formerly unraveled buyers' social ties the firm is able to separate the different types of buyers more precisely, thus it can design more profitable system of menus.

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Thank you for your attention!

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