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Keio Business School

Hidden Information and Sorting Potential Customers: The Applicability of Contract Theory Reconsidered II

Questions

1. Read the first half of Section 2. Suppose that the monopolist does not know which type each consumer is. Find a sufficient condition under which adverse selection occurs when the monopolist offers the menu of the first-best contract to consumers.
2. Read the second half of Section 2. Confirm the formulation of Problem (3) and the process for deriving the menu of the second-best contract.
3. In this case material, a mechanism for screening hidden information is applied to product design. Let us consider the application of the same mechanism to the organizational design in companies. First, specify some company and clarify the role and function of the middle management of that company, such as gathering and transmitting information, project management and monitoring subordinates' performance, etc. Then, consider how the organizational structure of the company will be changed when decision-making made by human middle managers is replaced with tasks solved by an automated decision-making mechanism incorporated therein.

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The aim of this case

If the role of middle managers are information transmission, monitoring and evaluating subordinates' performance, and motivating them, then how will the introduction of artificial intelligence change the organizational form of companies? This case material provides a general analytical tool for estimating those informational costs in organizations. As an example of the application, we here deal with screening customers' hidden preferences in a context of product design pertaining to quality and price in situations where adverse selection takes place, instead of analyzing employment contracts directly. "Adverse selection," along with "moral hazard," is a concept that was proposed in the 1950s by actuaries, with whom joint research by economists led to the formulation of a clear form of expression; it attributes one of the causes of inefficiencies in transactions in organizations to "hidden information." Readers should apply the analytical tool and try to consider changes in organizational structures due to the introduction of artificial intelligence. The mathematical knowledge that the discussion in this case material requires of the readers is differentiation of multivariate linear functions, although they will be able to follow the essential part of the text without knowledge on it.

1 Preface to the Discussion

Consider a situation where an insurer wishes to provide an insurance contract to the less accident-prone parties at a reasonable insurance premium. The insurer, however, cannot know who less accident-prone (more attentive) parties are. Under this **hidden information**, the insurer runs the risk of inadvertently providing contracts to the more accident-prone parties at this reasonable insurance premium. In this case, if there seems to be a high likelihood that the insurer will lose a significant amount, then the insurer will try to avoid this situation by hiking the insurance premium. At this higher premium, however, the less accident-prone parties may not bother to purchase insurance, resulting in a potential situation whereby insurance contracts will only be taken out with parties who are more accident-prone. This kind of selection due to hidden information, which leads to unintended consequences as the result of a lack of accurate information, is known as **adverse selection**.

As examples besides insurance contracts, in used automobile purchase agreements and loan contracts with financial institutions, parties not having private information sometimes engage in transactions with undesirable partners (sometimes only with such partners) and will incur unexpected losses. Suppose that borrowers are unlikely to be able to repay a loan, and that when it is difficult for lenders to accurately recognize such a situation that those lenders who have overestimated the possibility of default set a high interest rate. Then, some borrowers will end up moving to other loan contracts that can be financed on better terms, and only the borrowers for whom repayment is difficult may be left as potential trading partners for the lenders. This is the same phenomenon as adverse selection in the context of insurance contracts. Thus, the concept of adverse selection is currently applied to all phenomena due to hidden information.

Transaction history is sometimes used for mitigating adverse selection. In insurance contracts, for example, insurance premiums differ in accordance with the history of past accidents on the part of the insured parties, and banks will be wary of lending to firms with a history of default. A reputation for product's quality is important for the sellers and in cases where a product of inferior quality is discovered to have been made available for purchase without any change in price, sanctions will be imposed not only by the buyers of the product but also by other firms in the same industry. Suppose, however, that we are faced with a new transaction for which there is a complete lack of history and reputation of past transactions. Then, we cannot apply those measures to mitigate adverse selection that refers to the history or reputation of past transactions. We deal with this situation in this case material.

In addition, in order to prioritize analytical simplicity, the consideration undertaken here is focused on a configuration likened to the contract entered into between a **principal** and its **agent**, rather than a transaction mediated through the market. In this case material, the principal is the seller of a product and the agents are its customers. Typically, when analyzing a transaction by likening it to the contract entered into between a principal and its agent, the object of consideration thus formulated is called a **principal-agent problem** and the specific area of microeconomics that considers this type of problems is called **contract theory**.

The next section demonstrates how to derive **second-best contracts**. Consider a situation where agents can obtain benefit by making use of private information on their own preferences for a product. We consider the maximization of the expected profit that the principal can earn under this situation. This type of contracts are called the second-best contracts. The principal will sacrifice part of the benefit that he or she might have obtained in the case that there is no hidden information of the agents, in attempting to extract the agent's . As opposed to those second-best contracts, the contracts that maximize the principal's expected profits (or payoffs) in case of no hidden information agents have are called **first-best contracts**

2 Situation for Consideration

A monopolist is trying to produce a good with quality q. The unit cost of production is represented by $c(q)$, where $c(0) = c'(0) = 0$, and for $q > 0$, $c' > 0$ and $c'' > 0$. Each consumer wishes to purchase only one unit of this good, and there are two types of consumers who have different ratings for the quality. The monopolist does not know which type each consumer is, but knows from market surveys that there are N_α consumer of type α and N_β consumers of β type. The monopolist can produce the good with different quality for each type, and can offer different prices to consumers in accordance with the quality. For their part, after making their own observations, consumers can purchase the good at the price and quality offered for either type.

The utility functions for the two types of consumer are $u_\alpha = \alpha q - p$ and $u_\beta = \beta q - p$, where p is the amount paid when purchasing the good. Note that α and β represent the (maximum) amounts that the respective types of consumers are willing to additionally pay when the quality of the good improves by one unit. Here, it is assumed that $0 < \alpha < \beta$, and that the number of β-type consumers is small enough relative to the number of α-type consumers so that $\alpha(N_\alpha + N_\beta) > \beta N_\beta$ is satisfied.

Each consumer knows his or her own type and obtains a reservation utility 0 in the event that he or she does not purchase the good. In the following analysis, the principal is the monopolist presenting the contract menu that consists of the price and quality of the good, and the agents are the consumers who select transactions from the menu.[1]

First-best contract: agent's type is observable

As a preparation for confirming the occurrence of adverse selection in the situation mentioned above, it is assumed that the type of each consumer is observable by the monopolist or a third party. In this case, each consumer can only choose whether to accept the contract that is set for their own type. Consider what characteristics the first-best contract has. When (p_1, q_1) is set for α-type consumers and (p_2, q_2) is set for β-type consumers, the monopolist produces N_α units of the good for α-type and N_β units of the good for β-type. If the consumers accept the transaction, the consumer surplus (CS) and producer surplus (PS) are

$$\mathrm{CS} = N_\alpha(\alpha q_1 - p_1) + N_\beta(\beta q_2 - p_2),\ \mathrm{PS} = N_\alpha(p_1 - c(q_1)) + N_\beta(p_2 - c(q_2)).$$

From the viewpoint of social welfare, it would be desirable to maximize the total surplus (TS = CS + PS) generated from transactions. The total surplus maximization problem is formulated as

$$\max_{q_1, q_2} \quad \mathrm{TS} = N_\alpha(\alpha q_1 - c(q_1)) + N_\beta(\beta q_2 - c(q_2)). \tag{1}$$

By the first-order conditions, we obtain $\alpha = c'(q_1)$ and $\beta = c'(q_2)$. We write quality q_1 and q_2 of the good satisfying these conditions as q_α and q_β, respectively. Note that $q_\alpha < q_\beta$, because $0 < \alpha < \beta < \infty$ and $c' > 0$ for every $q > 0$.

Then, is it feasible for a transaction that maximizes the total surplus as a result of the profit maximization of the monopolist? The profit maximization problem of the monopolist is formulated as

$$\begin{aligned} \max_{p_1, q_1, p_2, q_2} \quad & \mathrm{PS} = N_\alpha(p_1 - c(q_1)) + N_\beta(p_2 - c(q_2)) \\ \text{s.t.} \quad & p_1 \le \alpha q_1,\ p_2 \le \beta q_2. \end{aligned} \tag{2}$$

[1] Setting a different price for each consumer is called first-degree price discrimination, and also known as perfect price discrimination.

The two constraints in Problem (2) guarantee that each type of consumer will accept this transaction and purchase the good, because their reservation utility is 0. Each condition is called **participation constraint** for the corresponding type. The monopolist can increase its profit by increasing the prices within the range where the participation constraints are satisfied, without changing product quality levels q_1 and q_2. Thus, Problem (2) becomes exactly the same as Problem (1), when we substitute $p_1 = \alpha q_1$ and $p_2 = \beta q_2$ into the objective function of Problem (2). Therefore, the monopolist sets $q_1^* = q_\alpha$ and $q_2^* = q_\beta$. The transaction with the maximum total surplus is realized as a result of the profit maximization of the monopolist. By $p_1^* = \alpha q_1^*$ and $p_2^* = \beta q_2^*$, however, the consumer surplus is zero. The monopolist obtains all the surplus generated from the transaction.

Second-best contract: agent's type is unobservable

Let $((p_a, q_a), (p_b, q_b))$ denote the menu of the second-best contract.[2] The profit maxi- mization problem of the monopolist is as follows.

$$\begin{aligned} \max_{p_a, q_a, p_b, q_b} \quad & N_\alpha (p_a - c(q_a)) + N_\beta (p_b - c(q_b)) & \\ \text{s.t.} \quad & \beta q_b - p_b \geq \beta q_a - p_a & (\text{IC}\beta) \\ & \alpha q_a - p_a \geq \alpha q_b - p_b & (\text{IC}\alpha) \\ & \beta q_b - p_b \geq 0 & (\text{PC}\beta) \\ & \alpha q_a - p_a \geq 0. & (\text{PC}\alpha) \end{aligned} \tag{3}$$

The first and second constraints in Problem (3) are conditions for consumers of each type to choose the contract set their own type. Each condition is called **incentive compatibility constraint** for the corresponding type. The third and fourth constraints are participation constraints. Let us simplify Problem (3).

(i) (PCβ) is negligible; the following inequalities hold.

$$\beta q_b - p_b \underset{(\text{IC}\beta)}{\geq} \beta q_a - p_a \underset{(\beta > \alpha)}{>} \alpha q_a - p_a \underset{(\text{PC}\alpha)}{\geq} 0$$

(ii) (ICβ) holds with equality; (PCβ) was negligible as shown in (i). Thus, if $\beta q_b - p_b > \beta q_a - p_a$, then the monopolist can increase its expected profit by raising p_b.

(iii) two possibilities

- (iii-1) If (ICα) holds with equality, then it must be that $q_a = q_b$ and $p_a = p_b$ (**pooling contract**), because (ICβ) also holds with equal as shown in (ii) and $\alpha \neq \beta$. We ignore (iii-1) here.

[2] In this section, we demonstrate how to design the second-best contract in a situation where adversary selection occurs. The technical insight used here is called **revelation principle**. There are some different versions of the principle, but the most widely used is the one proposed by Myerson (1979). Baron and Myerson (1982) applied the revelation principle to regulation problem of a natural monopoly industry.

- (iii-2) If (ICα) does not hold with equality (**separating contract**), then (PCα) holds with equality; if $\alpha q_a - p_a > 0$, then the monopolist can increase its profit by raising pa and pb by the same amount, keeping (ICβ).

(iv) (ICα) is negligible; (ICα) is rewritten as $\alpha q_a - p_a = 0 > \alpha q_b - p_b$ under (iii-2). By (PCβ), $\beta q_b - p_b \geq 0$. Thus, (ICα) holds, because

$$\beta q_b - p_b \underset{(\beta > \alpha)}{>} \alpha q_b - p_b.$$

By substituting (PCβ) and (PCα), which hold with equality, into the objective function of Problem (3), we have Problem (3) simplified as follows.

$$\max_{q_a, q_b} \; N_\alpha(\alpha q_a - c(q_a)) + N_\beta(\beta(q_b - q_a) + \alpha q_a - c(q_b)). \tag{4}$$

The first-order conditions of Problem (4) are

$$\beta = c'(q_b),$$
$$N_\alpha(\alpha - c'(q_a)) + N_\beta(-\beta + \alpha) = 0.$$

By the definition of q_β and the first equation of the first-order conditions, we have

$$q_b^* = q_\beta .$$

From (i), we have $\beta q_b^* - p_b^* > 0$, which implies that

$$p_b^* < p_2^* = \beta q_\beta .$$

Namely, by lowering the price, the monopolist induces β-type consumers to choose the menu set for those of that type, while the quality is maintained at the level of the first-best contract.

By the assumption that $\alpha(N_\alpha + N_\beta) > \beta N_\beta$, on the other hand, we have $c'(q_a) = \alpha - (N_\beta / N_\alpha) \cdot (\beta - \alpha) > 0$, which implies that

$$q_a^* < q_\alpha,$$

because $c' > 0$ and $c'' > 0$ for $q > 0$. From (iii-2), $p_a^* = \alpha q_a^*$, and thus

$$p_a^* < p_1^* = \alpha q_\alpha,$$

by $q_a^* < q_\alpha$. As compared with the first-best contract, the monopolist decreases the price and the quality of the product for α-type consumers. As a result, the unit cost of production is also reduced to $c(q_a^*)$. The profit of the monopolist is

$$N_\alpha(\alpha q_a^* - c(q_a^*)) + N_\beta(\beta q_b^* - c(q_\beta)).$$

Note that in the second-best contract, the consumer surplus is $N_\beta(\beta q_b^* - p_b^*) > 0$ by $u_\beta = \beta q_b^* - p_b^* > 0$.

References

[1] Baron, D. P and Myerson, R. B. (1982) “Regulating a Monopolist with Unknown Costs,” *Econometrica* 50, 911-930.

[2] Myerson, R. B. (1979) “Incentive Compatibility and the Bargaining Problem,” *Econometrica* 47 61-73.

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