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Nobel Laureates

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THE NOBEL PRIZE IN ECONOMIC SCIENCES 2007

Abstract

Leonid Hurwicz, Eric S. Maskin and Roger B. Myerson were awarded the Nobel Prize in Economic Sciences 2007 for having laid the foundations of mechanism design theory. The remarkable power of mechanism can be described as follows. Market systems in general and auctions in particular can be efficient economic institutions for the allocation of private goods. However, economic efficiency does not imply that an institution will be chosen by those participants who have the power to select it. Instead, one may expect the choice of economic institution to reflect the interests of the designer. Mechanism design theory can be used to analyse such situations and explain which mechanisms are preferred by the market participants, i.e. sellers and buyers. This is relevant not only for private goods, but in particular for public goods. Thus, L. Hurwicz, E. S. Maskin and R. B. Myerson developed a theory describing which market institutions will emerge.

Key words:

Asymmetric information, incentives, mechanism design theory, revelation.

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1. Topics in Information Economics: Moral Hazard and Adverse Selection

One major goal of economic theory is to analyse and to understand which institutions are best suited to minimize the economic losses generated by asymmetric information between buyers and sellers. Which economic institutions or allocation mechanisms will realize the largest gains from trade?

Information economics is a broad subject with many variations and applications. For example, one problem in information economics is moral hazard, where one party of an economic transaction may undertake some actions that affect the other party's welfare in result of the transaction that the second party cannot enforce or observe perfectly. One solution to the problem of moral hazard is the use of economic incentives. Whenever informational economic problems arise, it is natural to ask: what is the best contract that can be developed? Micro-economic theory investigates optimal contract and mechanism design focusing on the cases of adverse selection that makes use of the revelation principle.

Mechanism design theory, created by Leonid Hurwicz and further refined, developed and applied by Eric Maskin and Roger Myerson, provides tools for analysing and answering questions of this kind to give an individual decision-maker an incentive to consider the benefit (or loss) that others derive from his or her actions. The decision-maker can be a single individual or a household, or a region within a country, or even a country itself. When one country takes costly measures to reduce its output of carbon dioxide, any resulting reduction of global warming is a benefit which is captured by every country. When the spillover is complete, we refer to the commodity generating it as a pure public good. A good is a pure private good if the only person to benefit is the one doing the consuming. Any amount of the public good made available to one household or an individual can be simultaneously consumed by everyone in the region or country, although not everyone receives the same level of benefit. Truthful preference revelation is hard to elicit. Without very carefully designed incentives, individuals will be able to misrepresent their preference scheme in a way that significantly reduces their share in the financing cost of the public good. This would give the household a net increase in utility as against truthful revelation. Mechanism design theory shows why an auction is the most efficient economic institution for the allocation of private goods among a given number of potential consumers.

The mechanism design theory began with the work of Leonid Hurwicz (1960). He defined a mechanism as a communication system in which participants send messages to each other and where pre-specified rules assign outcomes for every collection of received messages. Within this framework, markets and market-like institutions could be compared with alternative institutions. At that time, much of the interest focussed on the information and costs of mechanisms, while abstracting from incentive problems. Later on, mechanism design theory became relevant for a lot of applications only after Hurwicz (1972) introduced the key notion of incentive compatibility. Incentive compatibility allows the analysis to incorporate the incentives of self-interested participants. In particular, it allows a rigorous analysis of economies and situations where agents are self-interested and have relevant private information.

In the following, we demonstrate the progression from contracts designed for a single party to the revelation principle and contracts and mechanisms designed for many interacting parties.

2. The Revelation Principle and Mechanism Design

We demonstrate mechanism design and revelation principle by introducing an example. The aim is to show that the mechanism design and the revelation principle have transformed the analysis of economic mechanisms.

2.1. Insurance contract designed for a single party

Assume an individual who will receive a risky amount of money income with which to consume. Specifically, the individual will receive either amount M_1 or M_2, where $M_1 > M_2$. The individual is risk averse. There is a probability p_j that the individual will get M_2 and $1 - p_j$ that money income will be M_1, where the subscript denotes either h (high) or l (low) risk. We assume that $p_h > p_l$. The individual knows whether he is a low risk or a high risk individual. Because the individual is at risk, he would like to insure against low level of income. He will give up some income in return for insurance against low money income. An insurance contract with a single insurance company specifies two numbers, m_1 and m_2, with $m_1 = M_1 - P$, and $m_2 = M_2 - P + B$, where P is the insurance premium and B is a benefit paid by the company in the bad state. The insurance company will have profits $M_1 - m_1$ in the good state and $M_2 - m_2$ in the low income state.

The insurance company does not know whether the individual is low or high risk; however, the company has a prior assessment that the household is high risk with probability *k*. What should the insurance company do? The company will not offer optimal contracts for the two types of individuals. If the company offers the optimal contracts for the two types of individuals, the individual -- whether high or low risk one -- is going to choose the contract optimally designed for the low risk type, since it gives a higher level of income in both states. The company can offer the optimal contract for the high risk individual alone, but then the low risk individual will refuse to buy.

We can solve the insurance firm's problems as follows. The insurance company offers two contracts, (m_1^h, m_2^h) and (m_1^l, m_2^l). The contract (m_1^h, m_2^h) is intended for the high-risk individual and the contract (m_1^l, m_2^l) for the low-risk household. If we assume that the individual chooses the contract intended for him, the company's expected profits are

$$k\left[(1-p_h)(M_1-m_1^h)+p_h(M_2-m_2^h\right]+(1+k)\left[(1-p_l)(M_1-m_1^l)+p_l(M_2-m_2^l\right]$$

This is what the firm would like to maximize. However, we have to make sure that the individual chooses the contract that is intended for him. Four constraints have to be fulfilled: The high risk individual must prefer (m_1^h, m_2^h) to his money income (M_1, M_2); the high risk individual must prefer (m_1^h, m_2^h) to (m_1^l, m_2^l). The low risk household must prefer (m_1^l, m_2^l), to money income (M_1, M_2); the low risk individual must prefer (m_1^l, m_2^l), to (m_1^h, m_2^h). These constraints are participation constraints and the incentive constraints for the high risk and low risk type.

In this example we have assumed that the optimal *mechanism* for the insurance company to use is to offer the individual a menu of two contracts. One intended for the individual if the type is low risk, and one intended for the high risk type. Perhaps some more complex scheme for the insurance will make more profits for the insurance company.

2.2. Optimal contracts for interacting market participants

Suppose that the government will procure one hundred units of a special good. There are two firms which could supply these goods. Each supplier has a linear cost structure, i.e. constant marginal cost and no fixed cost. However, the value of the MC_1 for firm *i* can be either 1 or 2, While each firm knows its own cost, neither the government nor the other firm knows the cost of the firm *i*. Both the government and the other firm believe that MC_1 is either 1 or 2 with probability 0.5 each. It is assumed that the government is in a position to propose contracts to the firms to which they must respond on a take-it-or-leave-it basis. If the government knew the costs of the supplier, its procurement would be solved as follows: The government proposes to buy from either firm if they have the same unit costs (or split its order between both firms) and to buy from the lower cost firm if one firm has marginal cost 1 and the other has cost 2. Since the government makes a take-it-or-leave-it offer, it will never pay more than the unit cost of the firm, which means that it pays 100 with probability 0.75 or 200 with probability 0.25 which leads to expected cost of 125. However, because the government is asymmetrically informed about the costs of the firm, it can not apply this scheme.

Suppose the government employs the following scheme: If both suppliers name 2, the order is split and the government pays 2 per unit. If both firms name 1, the order is split and the government pays $a > 1$ per unit. Suppose one firm names 1 and the other names 2, the order goes to the firm that name 1, and the government pays $b > 1$ per unit. What should a and b be, to get the firms to reveal truthfully their production cost? Assuming both suppliers try to maximize their expected profits, firm 1 truthfully reveals a cost of 1 if $50\frac{1}{2}(a-1)+100\frac{1}{2}(b-1)>25.$

It is the Nash equilibrium between the two suppliers to truthfully reveal their costs in this case. Let us assume that the firms truthfully reveal their costs of production. Then the government's expected expenditures are $100[1/4a+1/2b+1/4\cdot 2]$. This means, with probability 1/4 the government pays x per unit, with probability 1/2 it pays y per unit, and with probability 1/4 it pays 2 per unit of the supply. The truth inducing constraint can be written as $25a+50b>100$, and the government's objective function is to minimize $25a+50b+50$, so it is proved that any selection of a and b satisfies the constraint, and the equality gives minimum expected cost to the government. Expected costs are 150.

To sum up: We found a contract or scheme in which truth-telling is the Nash equilibrium, costing the government an expected cost of 150. But this scheme has multiple Nash equilibria for the two firms, one of which is better for both firms than the truth-telling. Thus, economic theory modifies the scheme in a way that makes truth-telling the unique Nash equilibrium. But truth-telling is not a dominant strategy. Therefore, the theory has to modify the scheme again, so that truth-telling becomes the dominant strategy for each firm.

In the foregoing analysis, we made two assumptions about the mechanism the government uses to award the contract. First, we assumed that the government would ask the firms to announce their costs, with the contract amounts and payments depending on the named costs. Second, it was assumed that the contract amounts and payments took a specific form. If one looks at different schemes, perhaps one can find what will lower the government's expected costs below 150. Can the government do better with some more complex sort of mechanism? The so-called revelation principle, developed by the Nobel Prize winners of 2007, shows that this cannot be done. Truth-telling in a direct revelation mechanism mimics every possible equilibrium outcome in every possible mechanism.

2.3. The revelation principle

A social choice rule must elicit information about individual preferences so that the outcome of the process will reflect these preferences. If an individual has an incentive to misrepresent its preference, that purpose of the rule is defeated. Is there a social choice institution that is not vulnerable to this kind of problem? To increase the probability of an affirmative answer, we use a social choice rule to include mechanisms.

There are three or more alternatives. A mechanism requires an individual to announce a message. This message could be a description of the individual's preference order; it could be the name of some alternative; it could be a list of numbers. Each particular mechanism will be based on a particular kind of message. The mechanism specifies which message is to be reported for each possible preference scheme. For instance, the market system asks you to choose an affordable consumption plan at which your marginal rate of substitution in consumption is equal to the price ratio. Let $s(R)$ denote the message that the individual is required to send when the true preference ordering is R. The mechanism specifies the outcome for each possible configuration of messages transmitted by the voters. Let y be the outcome for each individual message.

The referee observes the individual's message, but cannot tell whether this message equals $s(R)$, when R is the individual's true preference scheme. That is because R cannot be observed. The only way to ensure that the individual announces a message equal to $s(R)$ is to design a mechanism that provides incentives for the individual to do so. Economic theory wants this to be a dominant strategy.

3. Example

Mechanism design theory offers many results that may seem very abstract. In order to illustrate the underlying principles, the Royal Swedish Academy of Sciences presented a detailed analysis of an example. We use a similar example, adapted from Campbell (2006).

When a government sells a good, a right or an asset to the public, its objective should not be to maximize its revenue. Its goal should be to try that the good, the right or the asset goes to the agent with the highest reservation value. Suppose a good x is being allocated to the public. Assume that no production is involved. The individuals' preferences are given by $U(x, y) = B(x) + y$, where commodity x is the good being auctioned; good y is generalized purchasing power, that is, expenditure on everything but x. Assume that $B(0) = 0$. If the individual paid P for the unit of x, then the change in utility would be $dU = B(1) + dy = B(1) - P$. If $P < B(1)$, then dU is positive. The individual would be willing to pay any price P less than $B(1)$ for one unit of x because that would increase utility. But any price above $B(1)$ would cause utility to fall. Therefore, $B(1)$ is maximum that the individual would pay for one unit of x. That is, $B(1)$ is the individual's reservation value for one unit of x. The function B is different for different individuals, therefore we need one reservation value $B_i(1)$ for each individual i. To simplify the notation, we denote V_i as the reservation value.

Now we show that efficiency requires that the asset be awarded to the buyer with the highest reservation value. Suppose to the contrary that $V_i < V_j$ and i has the good. But then U_i and U_j will both increase if i transfers the good to j in return for $1/2V_i + 1/2V_j$ euros: The change in i's utility is $dU_i = -V_i + \frac{1}{2}V_i + \frac{1}{2}V_j = \frac{1}{2}V_j - \left(\frac{1}{2}V_i + \frac{1}{2}V_j\right) = \frac{1}{2}V_j - \frac{1}{2}V_i > 0$; and the change in j's utility is $dU_i = V_j - \left(\frac{1}{2}V_i + \frac{1}{2}V_j\right) = \frac{1}{2}V_j - \frac{1}{2}V_i > 0$. We have increased utility of both i and j, without affecting the utility of anyone else. Therefore, the original outcome was not efficient. We have implicitly assumed that individual j has $1/2V_i - 1/2V_j$ euros. Therefore we claim:

If V_H is the highest reservation value, and every individual $i \neq H$ has at least $1/2V_i - 1/2V_H$ units of commodity y, then allocation efficiency requires that the good be held by the individual whose reservation value is V_H.

Now suppose that neither the government nor the potential buyer knows how the other party values the good. Thus, they each have private information about their own valuation. What kind of mechanism could they use to trade with each other? One possibility is that the government makes a take-it-or-leave-it offer to the buyer. Another possibility is that the buyer makes such an offer to the government. A third possibility would be a so-called double action, a mechanism in which both parties simultaneously announce a price at which they are willing to trade. If the buyer's offer exceeds the government, they trade at the price half way between the two proposed prices or according to some other pre-specified splitting rule. However, none of these mechanisms has the property that trade always occurs if the buyer's reservation valuation is higher than that of the seller.

From the efficiency point of view, we want the asset to be allocated to the firm that delivers the highest net benefit to consumers. Therefore, one would to employ an auction mechanism that always allocates an asset, a good or a right to the firm with the highest reservation value, even when firms bid strategically. However, there is a problem of incentives. If the government asked each firm to report its reservation value, we would not get any truthful revelation. Every firm would have a strong incentive to overstate its value, to increase the probability in order to get the asset. But there are auctions that would give each firm an incentive to reveal its value truthfully. This is one subject of the revelation principle created and developed by Hurwitz, Maskin and Myerson.

4. Concluding Remarks

The 2007 Nobel Prize winners have shown that markets in general, and auctions in particular, can be efficient institutions for the allocation of private goods. Economic efficiency, however, does not imply that an institution be chosen by those who have the right to select it. Whereas the study of institutions is one application, mechanism design theory has a much broader range. For example, it has been used for the analysis in political science. The theory enables the analysis of institutions for the provision of public goods, the optimal design of regulation and voting schemes in politics. See, for example, the role of multilateral institutions in international trade cooperation (Maggi, 1999).

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