7. EXTERNALITIES AND PUBLIC GOODS

In many economic situations, markets are not complete. Certain actions of a firm or a consumer may affect other economic agents' welfare but are not market transactions. These are situations where there exist externalities. Classical examples include flowers in one's backyard increasing the utilities of the people who walk by and pollution generated by a firm reducing the welfare of other people. Another situation where markets are not complete is the existence of some good the use of which by one agent does not preclude its use by other agents. In this case, an individual may be able to consume the good without paying for it. This is what we often call the case of public goods. In the presence of externalities and/or public goods, competitive equilibrium need not be efficient any more. The essential economic questions to be answered are how market equilibrium is affected and what kind of institutional arrangements can be made that would improve economic efficiency.

7.1 A Simple Bilateral Externality

Suppose that there are two consumers, 1 and 2. Consumer i's consumption of the L traded goods is $x_{1i}, ..., x_{Li}$. (The analysis will be similar if we had two firms or one firm and one consumer.) Consumer 1 also consumes h amount of a good that is not traded in the market, which affects the well-being of consumer 2. The utility functions of the consumers are $u_i(x_{1i}, ...x_{Li}, h)$. Assume that the market prices for the L traded goods are taken as given by the two consumers, and consumer $i's$ wealth is w_i. Suppose that each consumer chooses x_{li} optimally for any level of h, we can write the derived utility function over the level of h as

$$\begin{aligned} v_i(p, w_i, h) &= \max_{x_{li} \geq 0} \; u_i(x_{1i}, ...x_{Li}, h) \\ s.t. \; \sum_l p_l x_{li} &\leq w_i. \end{aligned}$$

Further assume that $u_i(x_{1i}, ...x_{Li}, h)$ is quasilinear with respect to a numeraire good, say x_{1i}, and call the other traded goods x_{-1i} and let $u_i(x_{1i}, x_{-1i}, h) = f_i(x_{-1i}, h) + x_{1i}$. Then the optimal consumption of x_{-1i}, $x_{-1i}(\cdot)$, is independent of $i's$ wealth, and therefore

$$v_i(p, w_i, h) = f_i(x_{-1i}(p, h), h) - p \cdot x_{-1i} + w_i.$$

Now let

$$\phi_i(p, h) = f_i(x_{-1i}(p, h), h) - p \cdot x_{-1i},$$

we have

$$v_i(p, w_i, h) = \phi_i(p, h) + w_i.$$

Since p is taken as given, we can suppress it and write

$$v_i(w_i, h) = \phi_i(h) + w_i.$$

Assume $\phi_i''(h) < 0$, and $\phi_2'(h) \neq 0$.

In a competitive equilibrium, consumer 1 chooses h^* to maximize $\phi_1(h)$. The necessary and sufficient condition is

$$\phi_1'(h^*) \leq 0, \text{ with equality if } h^* > 0.$$

On the other hand, Pareto optimality requires h to solve the joint surplus of the consumers, $\phi_1(h) + \phi_2(h)$, with the necessary and sufficient condition as

$$\phi_1'(h^o) + \phi_2'(h^o) \leq 0, \text{ with equality if } h^o > 0.$$

Assume interior solutions obtain in each of the above cases, then $\phi_1'(h^*) = 0$ in a competitive equilibrium but Pareto optimality requires $\phi_1'(h^o) + \phi_2'(h^o) = 0$. Thus the competitive equilibrium is not efficient. When $\phi_2'(h) < 0$, which is case of negative externalities, $h^* > h^o$. When $\phi_2'(h) < 0$, which is the case of positive externalities, $h^* < h^o$. We often say in such cases that there are market failures.

One solution to correct the market failures caused by externalities is to use government interventions, such as taxes (subsidies) or quotas. If the government can measure the consumption of h by consumer 1 and also knows consumers' utility functions, then a tax (or subsidy) can restore the efficiency. To see this, suppose that the government imposes a tax $t = t_h = -\phi_2'(h^o)$ for each unit of consumption of h by consumer 1. Then consumer 1's optimal choice of h will maximize

$$\phi_1(h) - t_h h = \phi_1(h) + \phi_2'(h^o)h,$$

which must have the solution h^o. (If $\phi_2'(h) > 0$, then the government provides a subsidy which is a negative tax.)

Another school of thoughts is that government intervention may not be needed for efficiency even in the presence of externalities. The idea is that if property rights are well defined and if bargaining is efficient, then the two consumers can reach the efficient outcome by themselves without government intervention. To see this, suppose consumer 2 has the property right of having zero externalities ($h = 0$), and the bargaining takes the form of consumer 2 making a take-it-or-leave-it offer to consumer 1. Then consumer 2 can make an offer that allows consumer 1 to consume h by paying T to consumer 2. Consumer 2 thus solves

$$\begin{aligned} &\max_{h\geq 0, T} \ \phi_2(h) + T \\ s.t.\ \phi_1(h) - T \ &\geq \ \phi_1(0). \end{aligned}$$

In the optimal, the constraint is binding, and thus the problem becomes

$$\max_{h\geq 0} \ \phi_2(h) + \phi_1(h) - \phi_1(0),$$

which has the solution h^o, the socially efficient level.

You should check that if consumer 1 has the right to generate as much h as she wants, or if the surplus in bargaining is shared in any other manner, the efficient outcome will also be obtained. This result, that if trade for externality can occur and if there is no transaction cost, bargaining will lead to efficient outcome no matter how property rights are assigned, is often called the Coase Theorem. (This result comes from a paper by Coase entitled "The Problem of Social Costs", which you should read at some point of your graduate study.) Be careful about the assumptions behind the Coase Theorem.

7.2 Public Goods

A concept that is closely related to that of externality is public goods. A public good is a commodity for which the use of it by one agent does not preclude its use by other agents. In other words, it is nondepletable in the sense that consumption by one individual does not affect the supply available for other individuals. Examples include national defence, knowledge, and clean air. In contrast, a good is private. or depletable, if for each unit consumed by one individual, there is one unit less available for other individuals.

We shall be mainly concerned with those public goods whose consumption no individual can be excluded from.

Suppose that there are I consumers and one public good, in addition to L private goods. The provision of the public good is x, and consumer $i's$ derived utility from consuming the public good is $\phi_i(x)$. Also, the cost of providing q units of the public good is $c(q)$, and assume $\phi_i'(\cdot) > 0$, $\phi_i''(\cdot) < 0$, $c'(\cdot) > 0$, $c''(\cdot) \geq 0$. With $x = q$, the Pareto optimal allocation must solve

$$\max_{q \geq 0} \sum_i \phi_i(q) - c(q)$$

The necessary and sufficient condition for the optimal solution is

$$\sum_i \phi_i'(q^o) \leq c'(q^o), \text{ with equality if } q^o > 0.$$

On the other hand, if there is a competitive market for the public good and the price for each unit of the public good is p. Consumer i can choose to buy x_i units of the public good and $x = \sum_i x_i$. At a competitive equilibrium, $p = p^*$, each consumer chooses her own consumption that solves

$$\max_{x_i \geq 0} \ \phi_i(x_i + \sum_{k \neq i} x_k^*) - p^* x_i.$$

The necessary and sufficient condition for the optimal solution is, letting $x^* = \sum_i x_i^*$,

$$\phi_i(x^*) \leq p^*, \text{ with equality if } x_i^* > 0.$$

The equilibrium production of public good by firms must satisfy

$$p^* \leq c'(q^*), \text{ with equality if } q^* > 0.$$

The market clearing condition implies that $x^* = q^*$. Now suppose $q^* > 0$. Thus for some i we have $\phi_i(q^*) = p^*$ and it then follows that $\phi_i(q^*) = c'(q^*)$. But since $\phi_i'(\cdot) > 0$, we have

$$\sum_i \phi_i'(q^*) > c'(q^*)$$

whenever $I > 1$. Compare q^* with q^O, and since ϕ_i is strictly concave and $c(\cdot)$ is convex, we have $q^* < q^O$. The provision of public goods in a competitive equilibrium is too low compared to the socially efficient level. This inefficiency can be readily explained in terms of externalities. When an individual purchases some quantities of public goods, she exerts a positive externality on other individuals who will also benefit from more public goods. But the individual does not take such benefits into account. This is also called the free-rider problem: each person wants to enjoy the public good provided by other people, but is unwilling to contribute to the public good for the benefits of others.

The inefficiency can potentially be overcome through government interventions. One possibility is for the government to provide the public good directly.

7.3 Private Information and Second-Best Solutions

We have so far assumed perfect information in our study of externalities and public goods. We have seen that competitive equilibrium need not be efficient in the presence of externalities and public goods, but we have also argued that efficiency can be fully restored in some situations through the market mechanism and more generally through government interventions. When there is asymmetric information, however, in general we may not be able to obtain full efficiency in the presence of externalities and/or public goods. An interesting research area is then to study what kind of institutional arrangements or mechanisms that would achieve the second-best outcomes. In particular, it might now matter how the bargaining is conducted, whether quota or tax is used, and so on.

Let me explain this a little more for the case of bilateral externality involving a firm and a consumer. Consider a situation with one firm and one consumer (Alternatively, we can think of two firms or two consumers). Suppose that the externality generated by the firm can have only two values: $h = 0$ or $h = H$. When $h = 0$, the benefit and cost to both the firm and the consumer are zero. When $h = H$, the firm receives benefit b, and the consumer receives cost c. b and c are realizations of independently distributed continuous random variables on $[b_1, b_2]$ and $[c_1, c_2]$ with c.d.f. being $G(b)$ and $F(c)$ respectively and p.d.f. being $g(b)$ and $f(c)$ respectively. Assume $b_2 > c_1$. The firm privately learns its b and the consumer privately learns her c. Both the firm and the consumer want to maximize the expected monetary payoffs.

In this case, bargaining between the two parties in general may not lead to efficient outcomes. To see this, first notice that Pareto efficiency would require that $h = H$ if and only if $b > c$. Next, suppose that the consumer has the right of having $h = 0$ and can make a take-it-or-leave-it offer to the firm which allows the firm to generate

$h = H$ for a transfer payment of T. Then the consumer solves the following problem:

$$\max_{T} \ (T - c)[1 - G(T)].$$

The solution to this problem satisfies

$$T^* = c + \frac{1 - G(T^*)}{g(T^*)}.$$

Then for any $c < b_2$ we must have $T^* > c$. But the consumer's offer will be accepted by the firm if and only if $b \geq T^* > c$. Thus $h^* = 0$ when $T^* > b > c$, which is not Pareto efficient.

Inefficiency can also arise if the firm can make a take-it-or-leave-it offer. In this case, the firm solves problem

$$\max_{T} \ (b - T)F(T).$$

The solution to this problem satisfies

$$T^* = b - \frac{F(T^*)}{f(T^*)}.$$

Then for any $b > c_1$, we must have $b > T^*$. But the firm's offer will be accepted by the consumer if and only if $T^* \geq c$. Thus $h^* = 0$ when $b > c > T^*$, which is again not Pareto efficient.

Note that, contrary to the situations under complete information, it could matter in terms of efficiency who has all the bargaining power under incomplete information. To see this point, suppose that only the firm has private information and c is common knowledge. Then full efficiency can be achieved as long as the firm can make take-it-or-leave-it offers, because the firm knows that it has to offer $T = c$ in order to generate $h = H$, and it will offer $T = c$ if and only if $b > c$. Similarly, if only the consumer has the private information and b is common knowledge, then the consumer should have all the bargaining power to achieve Pareto efficiency.

More generally, the problem is one of designing optimal mechanisms, which is an interesting area of research. In the present problem with two-sided asymmetric information between the firm and the consumer, for instance, there is a simple mechanism the government can use that would ensure the efficient choice of h.

The mechanism works as follows: The firm and the consumer are each asked to report their values of b and c, respectively. Let $\widehat{b}$ and $\widehat{c}$ denote these reports. The government announces that it will allow $h = H$ if and only if $\widehat{b} > \widehat{c}$. In addition, if $h = H$, the government will tax the firm an amount equal to $\widehat{c}$ and will subsidize the consumer with a payment equal to $\widehat{b}$.

Now, if the firm and the consumer will always report b and c truthfully, then we must have the efficient outcome with $h = H$ if and only if $b > c$. It remains to show that the firm and the consumer will indeed be truth-telling. We show this by arguing that truth-telling is a weakly dominant strategy for the firm and for the consumer. Suppose the firm's true benefit is b. If it reports $\widehat{b} > b$, the firm will receive the same payoff as if it reports $\widehat{b} = b$ when $\widehat{c} > \widehat{b}$ or when $b > \widehat{c}$, but the firm's payoff will be $b - \widehat{c} < 0$ if $\widehat{b} > \widehat{c} > b$. Thus any strategy $\widehat{b} > b$ is weakly dominated by $\widehat{b} = b$. If the firm reports $\widehat{b} < b$, the firm will have the same payoffs as if it chooses $\widehat{b} = b$ when $\widehat{c} < \widehat{b}$ or when $\widehat{c} > b$, but the firm's payoff will be 0 when $b > \widehat{c} > \widehat{b}$ while it could obtain $b - \widehat{c} > 0$ by reporting $\widehat{b} = b$. Thus any strategy with $\widehat{b} < b$ is weakly dominated by $\widehat{b} = b$. Thus $\widehat{b} = b$ is a weakly dominant strategy for the firm. Similarly we can show that $\widehat{c} = c$ is a weakly dominant strategy for the consumer.

This mechanism is an example of what comes to be known as the Groves-Clarke mechanism initially proposed for deciding the provision of a public project. Notice that under this mechanism although the externality level is chosen optimally in our example, the government's budget is in general not balanced, which could create other distortions.