ISSN: 2472-3703 DOI: 10.6911/WSRJ.202211_8(11).0011

Analysis of Competitive Market Efficiency Under Consumption Pollution Externalities

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Abstract

This paper considers the public externality effect of consumption pollution (assuming no pollution in production). Using the basic model, it is proved that the perfectly competitive market is Pareto efficient. This conclusion shows that externalities do not necessarily lead to market failure. Although pollution leads to changes in the quantity (or quality) of ecological resources (ecological environment), such changes provide accurate stimulation to consumers and guide their consumption behaviors to achieve Pareto optimization in perfectly competitive market. Environmental policies should focus on ecological sustainability. Ecological environment (quality) is the result of consumers' choice of economic behavior. Under ecological sustainability, environmental taxes make the economy inefficient.

Keywords

Consumption pollution public externalities competitive economy efficiency.

1. INTRODUCTION

The ecological environment (like fresh air and clean water) is a public good, It will be affected by production and consumption pollution. According to the classification of external effects by Bator (1958), only public external effects are considered here. Such as air pollution and water pollution caused by production or consumption, and climate change caused by carbon emissions in the atmosphere, once these pollutants lead to changes in the ecological environment, the impact on all people is the same. In reality, this kind of public external effect has more important significance for environmental policy.

The early research came from the field of production. Since no price provides an incentive to reduce pollution, the externality of producing pollution must create an excessive demand for environmental capacity. As for the distortion of resources caused by such external effects, the analysis result of Olson And Zeckhauser (1970) is that Pigouvian tax is levied on pollution producers, while there is no need for any incentive for victims. Subsequent literature on externalities illustrates the limitations of Pigouvian tax laws and the many alternative policy instruments, including subsidies for pollution reduction and a system of transferable emission permits. Different policy instruments are adapted to different environmental pollution problems. Turvey (1963) proved that Pigouvian taxes themselves can also lead to misallocation of resources. Coase (1960) proposed to eliminate distortions caused by external effects through the definition of property rights. In the case of a minority, it is demonstrated that an efficient outcome will be achieved. However, this efficient method is not suitable for large numbers of people, such as the public pollution caused by consumption: car exhaust, water

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pollution, carbon emissions and so on. Such issues involve a large number of people and the cost of both defining property rights and reaching a negotiated agreement is high. As productivity has increased dramatically, so has human consumption. The impact of consumption pollution on the ecological environment has become a feature of this era. In the basic externalities model, only pollution caused by production activities is considered. It does not discuss the pollution caused by consumption behavior. The pollution caused by consumption is different from the pollution caused by production. The producer maximizes his profit, and the consumer is maximizing his utility. Therefore, the two types of pollution have different effects on market efficiency.

Unlike the issues explored in the basic model, in our model only consumption is considered to produce pollution (production is not). Consumption pollution leads to changes in the ecological environment (public goods), which also affects the utility of consumers. Using the description method of the basic model, the Pareto optimal conditions are given first. Then the conditions of perfect competitive market equilibrium are derived and compared. In the case that the solution is unique, we prove that the perfectly competitive market is Pareto efficient. The corresponding policy suggestion is that environmental policy should focus on sustainability. Under sustainable conditions, ecological environment (quality) is the result of efficient economic operation, which has certain guiding significance for environmental policy making.

2. DESCRIPTION OF MODEL

The production activities of the firms are pollution-free and consumers produce pollution in A perfectly competitive market. Pollution has public externalities.and the level of pollution depends on the total amount of goods consumed.For example, air pollution is caused by consumers using cars. Air pollution is a public good with public externality, and it has the same negative utility for every individual. Part of consumption pollution is absorbed by the ecological environment and will not harm consumers. And the other part that exceeds the assimilative capacity of the environment is accumulated in the natural environment, which cause continuous harm to consumers. In a perfectly competitive market, the firms decides the output under the market price, and the consumer decides to consume the quantity of goods under the market price.

The model uses the following mathematical notation:

There are m consumers: j=1, 2,------,m; and There are h firms: k=1,2,---,h.

N goods are produced and consumed, i =1, 2, ------, n.

x_{ij} – The amount of good (resource) i consumed by individual j, $i = 1,2,\ldots n$; $j = 1,2\ldots m$

y_{ik} – The amount of good (resource) i produced by firm k, $i = 1,2,\ldots n$; $k = 1,2\ldots h$

r_i – – – The total quantity of (resource) i available to the community , $i = 1,2,\ldots n$.

$S(\sum_i^n \sum_j^m x_{ij})$ – – – reduction of ecological resources caused by consumption pollution

The amount S of reduction of ecological resources caused by consumption pollution is related to the total amount $\sum_i^n \sum_j^m x_{ij}$ of consuming goods.

$$\sum_j^m x_{ij} - \sum_k^h y_{ik} \le r_i \text{ --- The resource availability constraints } i = 1,2\ldots, \text{ n} \quad (1)$$

$$f^k(y_{1k}, y_{2k},\ldots, y_{nk}) \le 0 \text{ --- The production set of firm } k, k = 1,2\ldots h. \quad (2)$$

$$u^j(x_{1j}, x_{2j},\ldots, x_{nj}, z) \text{ --- The utility function for individual } j, j = 1,2\ldots m. \quad (3)$$

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$x_{ij} \geq 0, i = 1,2,..n; j = 1,2..m$.

The production function f^k of the firm k is determined by the basic assumptions of production technology.the feasible production set for each firm is a set of technical constraints that are twice differentiable and define convex production possibility set.

In the utility function U^j of consumers j, z represents the quantity of ecological resources or environmental quality. Utility functions have first and second derivatives and are strictly quasi-concave, satisfying:

$$\frac{\partial u^j}{\partial x_{ij}} \geq 0 \quad \frac{\partial u^j}{\partial z} \geq 0 \quad \frac{\partial^2 u^j}{\partial x_{ij}^2} \leq 0 \tag{4}$$

On the one hand, the change of the quantity or quality z of ecological resources depends on the regeneration quantity of ecological resources; On the other hand, its reduction depends on the amount S of pollution produced by the number of goods consumed by consumers.

Thus the changes of ecological resources quantity (or quality) as follows:

$$z - z_0 = \delta z_0 - S(\sum_{i=1}^{n}\sum_{j=1}^{m} x_{ij}) \tag{5}$$

$$z = (1+\delta)\ z_0 - S(\sum_{i=1}^{n}\sum_{j=1}^{m} x_{ij}) \tag{6}$$

where z_0 is the quantity of ecological resources before pollution of consumption. δz_0 is the regenerated quantity of ecological resources(the service flow of endowment z_0). δ is a constant, which represent the ecological resources will grow at rate δ. The quantity of ecological resources change z-z_0 depends on the quantity z_0 of ecological resources before pollution and the regeneration speed δ of ecological resources, as well as the reduction S of ecological resources caused by pollution.

3. PARETO OPTIMAL CONDITIONS UNDER EXTERNAL EFFECTS OF PUBLIC POLLUTION

Let the utility function of any arbitrarily chosen individual (say individual 1) be maximized and subject to the requirements that there be no consequent loss to any other individual, and that the constraints constituted by the production functions and the availability of resources are satisfied. The Pareto optimal problem is to:

$$\begin{cases} \max\ u^1(x_{11}, x_{21},..., x_{n1}, z) \\ u^j(x_{1j}, x_{2j},..., x_{nj}, z) \geq u^{*j} \quad j = 2,..., m \\ f^k(y_{1k}, x_{2k},..., x_{nk}) \leq 0 \quad k = 1,2,\cdots, h \\ \sum_{j}^{m} x_{ij} - \sum_{k}^{h} y_{ik} \leq r_i \quad i = 1,2\cdots, n \\ x_{ij} \geq 0 \quad y_{ik} \geq 0 \end{cases} \tag{7}$$

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202211_8(11).0011

Here, $z = (1+\delta)z_0 - S(\sum_{i=1}^{n}\sum_{j=1}^{m} x_{ij})$

Because of our following concavity-convexity assumptions we can use the Kuhn-Tucker theorem to characterize the desired maximum. Let's do the Lagrangian as follows:

$$\mathrm{L} = \sum_{j=1}^{m} \lambda_j [u^j(x_{1j}, x_{2j}, \ldots, x_{nj}, z) - u^{*j}] - \sum_{k=1}^{h} \mu_k f^k(.) + \sum_{i=1}^{n} \omega_i (r_i - \sum_{j=1}^{m} x_{ij} - \sum_{k=1}^{h} y_{ik})$$

Differentiating in turn with respect to the *Xij* and *Yij*, we can obtain the Kuhn - Tucker condition as follows:

$$\begin{cases} x_{ij} \geq 0 \quad \lambda j(\frac{\partial u^j}{\partial x_{ij}} + \frac{\partial u^j}{\partial z}\frac{\partial z}{\partial x_{ij}}) - \omega_i \leq 0 \\ x_{ij}[\lambda j(\frac{\partial u^j}{\partial x_{ij}} + \frac{\partial u^j}{\partial z}\frac{\partial z}{\partial x_{ij}}) - \omega_i] = 0 \end{cases} \tag{8}$$

$$\begin{cases} y_{ik} \geq 0 \quad -\mu_k \frac{\partial f^k}{\partial y_{ik}} + \omega_i \leq 0 \\ y_{ik}[-\mu_k \frac{\partial f^k}{\partial y_{ik}} + \omega_i] = 0 \end{cases} \tag{9}$$

In the Lagrangian, we may take $\lambda_1=1$, $u^{*j}=0$. Associated with the inequality constraints we also have the corresponding complementary slackness conditions:

$$\lambda_j [u^j(x_{1j}, x_{2j}, \ldots, x_{nj}, z) - u^{*j}] = 0$$

$$\mu_k f^k(.) = 0$$

$$\omega_i (r_i - \sum_{j=1}^{m} x_{ij} - \sum_{k=1}^{h} y_{ik}) = 0$$

We assume that the feasible set of consumption complexes for each consumer is convex, closed, bounded form below in the x's, and contains the null vector, that the utility function that represents each person's preference is twice differentiable, quasi-concave, and increasing in the x's. Under these circumstances, as is well-known, the solution to the maximization problem that is about to be described exists and is unique.

4. MARKET EQUILIBRIUM CONDITION UNDER PERFECT COMPETITION

In this section, we first consider the requirement of market equilibrium. Both equilibrium of consumer and of firm in perfect competitive market is discussed as follow. The consumer is taken to minimize the expenditure necessary to achieve any given level of utility U^{*j}, so that in Lagrangian from the problem is to find the saddle value of

$$\mathrm{L_j} = \sum_{i=1}^{n} p_i x_{ij} + \alpha_j [u^{*j} - u^j \ (x_{1j}, x_{2j}, \ldots, x_{nj}, z)] \quad x_{ij} \geq 0$$

where α_j is a Lagrangian multiplier and *Pi* is price of commodity i. We immediately obtain the Kuhn-Tucker conditions:

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202211_8(11).0011

$$\begin{cases} p_i - \alpha_j\left(\frac{\partial u^j}{\partial x_{ij}} + \frac{\partial u^j}{\partial z}\frac{\partial z}{\partial x_{ij}}\right) \geq 0 \\ x_{ij}\left[p_i - \alpha_j\left(\frac{\partial u^j}{\partial x_{ij}} + \frac{\partial u^j}{\partial z}\frac{\partial z}{\partial x_{ij}}\right)\right] = 0 \end{cases} \tag{10}$$

Similarly the goal of the (competitive) firm is taken to be maximization of the profits subject to theconstraint given by its production relation $f^k(.)\leq 0$, Its Lagrange function is as follows:

$$L_k = \sum_{i=1}^{n} p_i y_{ik} - \beta_k f^k(.) \quad y_{ik} \geq 0$$

The Kuhn - Tucker condition is as follows:

$$\begin{cases} p_i - \beta_k \frac{\partial f^k}{\partial y_{ik}} \geq 0 \\ y_{ik}\left[p_i - \beta_k \frac{\partial f^k}{\partial y_{ik}}\right] = 0 \end{cases} \tag{11}$$

Note that competitive equilibrium is characterized by condition (10) and (11), and the Pareto-optimal under resources and production constraints is characterized by condition (8) and (9).

By comparing condition (8) and (10), we can find that condition (8) and (10) are exactly the same if there are $P_i=\omega_i$ and $\mu_k=\beta_k$. Similarly, by comparing condition (9) and (11), we can also see that condition (9) is identical with condition (11) if there are $\alpha_j=\lambda_j$. Thus these systems will have the same solution if they are unique.

Proposition: Given the assumed concave and convex conditions, then the allocation of resources in perfect competition market under the external effect of consumption pollution reaches Pareto optimum.

5. CONCLUSIONS AND RECOMMENDATIONS

We can see from the propositions obtained from the model analysis that the externality does not necessarily lead to market failure. In the public external effect of consumption pollution, consumers choose between ecological environment and consumer products. The environment gives the polluters, consumers, precise incentives so that the public externalities of their consumption do not lead to market failures. Although the market is effective, it does not guarantee ecological sustainability. The state of ecological environment depends on people's behavior of maximizing interests. If ecological resources are sustainable, it can be seen from Equation (5) that the service flow δz_0 of the ecological resource endowment must be greater than the amount S of ecological resource reduced by consumption pollution, i.e

$$\delta z_0 > S\left(\sum_{i=1}^{n}\sum_{j=1}^{m} x_{ij}\right) \tag{12}$$

At this time, the endowment of ecological resources has not been reduced ------ Ecologically sustainable. In such a case, the market is still efficient even if the price of the ecological resource product (service flow) is equal to zero. On the contrary, if the price of ecological resource products is greater than 0, it will lead to market inefficiency. In particular, since natural capital (ecological resource endowment) is not reduced, but also the utility of consumers is not reduced (Pareto effective), thus the social economy

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achieves sustainable development. In the case of sustainability, environment and consumption are the result of public choice and are efficient. If environmental taxes or pricing ecological products (δz_0) are imposed solely to improve environmental quality, it will lead to misallocation of resources and inefficiency of economy. The standard of the environment is not higher is better, and sustainability is the minimum standard. Therefore, the key lies in the sustainability of ecological resources.

If formula (12) does not hold, it means that although market economy is efficient, ecological resources are not sustainable. In this case, market efficiency and ecological resource sustainability cannot go hand in hand. In the long run, the endowment of ecological resources is constantly decreasing, and the unsustainability of ecological resources will also lead to the decline of utility (utility depends on the quantity Z of ecological resources). Thus, social and economic development is not sustainable. In fact, this is a contradiction between short-term market efficiency and long-term ecological unsustainability, as well as a problem of rapid economic development in modern society. It is generally accepted that the issue of ecological resource sustainability is primarily one of intergenerational "equity" rather than "efficiency". Therefore, the sustainability of ecological resources will become a constraint to social and economic development, especially when natural capital (ecological resources) and man-made capital are irreplaceable. A further question worth exploring is how to achieve the efficiency of the market under the condition of ecological sustainability.

ACKNOWLEDGMENT

This work was supported by the Project of the National Social Science Fund of China (grant number 17BYJ066, 2017-2021).

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