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Subsidies are Not Always Beneficial to Beneficiaries*

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Abstract We study the effects of subsidies on agents competing with each other. Examples include R&D competition of firms, local governments' expenditure to stimulate local markets, and election campaigns for political parties. We find that subsidies reduce social welfare and are not always beneficial for beneficiaries.

Keywords Subsidies, negative externality, R&D investment, welfare effect.

JEL Classification C72, D72, H25, O31, O38.

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1. INTRODUCTION

In many circumstances, governments provide subsidies to firms, institutions, and individuals to stimulate their activities. For example, the government subsidizes firms to encourage R&D, local governments to stimulate the local economies, political parties to offset the costs of election campaigns, and so on. These subsidies are provided for various purposes, such as promoting activities with positive externalities or alleviating unfair competition based on financial capacity. Even when subsidies are not aimed at improving the welfare of individuals who receive them, it is generally believed that subsidies improve the welfare of those who directly receive them and the welfare of society.

We show that such beliefs are not always true. That is, subsidies do not always benefit beneficiaries even when the government intends to do so, and can deteriorate social welfare. In particular, if individuals are strategically interdependent and their actions cause a negative externality to others, the beneficiaries' welfare may decrease after a subsidy is provided. This is, intuitively, because subsidies induce individuals to move in the direction that the government intends, increasing the negative externalities they have on each other. If the effect of the negative externalities outweighs the direct benefits that the subsidy provides to individuals, it can reduce the beneficiaries' welfare. Of course, subsidies can increase the beneficiaries' welfare. However, since subsidies are a form of social cost, subsidies stimulating individual actions and thus causing negative externalities always reduce social welfare.

Because subsidies are one of the main policy instruments of governments, many studies have been conducted on their effects. Our study is particularly related to the studies on the effect of subsidies for the individuals who are strategically interdependent. For example, Kleer (2010), Gil-Moltó *et al.* (2011), Kesavayuth and Zikos (2013), Lee and Park (2021), and Chen and Lee (2023) analyze the effects of R&D subsidies to firms competing in a market, and Roberts (1992), Andreoni and Bergstrom (1996), Kirchsteiger and Puppe (1997), and Akai and Ihori (2002) focus on subsidies to encourage the provision of public goods. None of these studies suggest that subsidies could reduce the welfare of beneficiaries. Our paper is also related to Kimmel (1992) and Zhao (2001), which show that a reduction in production costs can have a negative effect on the profits of firms in Cournot competition, because subsidies have the effect of reducing firms' production costs. However, in this paper, we focus on the welfare effects of subsidies in general situations (including Cournot competition) and suggest when subsidies are not beneficial to the beneficiaries.

2. BASIC ANALYSIS

There are two agents (1 and 2) who decide how much effort to make to acquire a benefit. Let x_i be agent i's effort. Let $U^i(x_i,x_j)$ be agent i's benefit when the agents choose (x_i,x_j). The benefits of the agents are symmetric, in that for any (x_i,x_j) and $(x'_i,x'_j)=(x_j,x_i)$, $U^i(x_i,x_j)=U^j(x'_i,x'_j)$. Agent i pays cost $C(x_i)$ to make effort x_i, and some of this cost is covered by subsidies from the social planner (the government). We assume that $U^i(x_i,x_j)$ and $C(x_i)$ are twice differentiable. Let $s\in[0,1]$ be the subsidy rate from the social planner. Agent i's payoff for (x_i,x_j) is his benefit minus the cost he actually pays:

$$V^i(x_i,x_j;s)=U^i(x_i,x_j)-(1-s)C(x_i).$$

Given agents' efforts (x_i,x_j), aggregate welfare is defined as[1]

$$W(x_i,x_j)=U^i(x_i,x_j)+U^j(x_i,x_j)-C(x_i)-C(x_j).$$

For convenience, let $U^i_k(x_i,x_j)=\frac{\partial U^i(x_i,x_j)}{\partial x_k}$ and $U^i_{kl}(x_i,x_j)=\frac{\partial^2 U^i(x_i,x_j)}{\partial x_k \partial x_l}$ for $k\in\{i,j\}$ and $l\in\{i,j\}$. To ensure the interior solutions for the problems we will consider, we assume that, for any x_j, $U^i(x_i,x_j)$ is strictly concave in x_i (i.e., $U^i_{ii}(x_i,x_j)<0$), $U^i_i(0,x_j)>0$ is high enough, and $\lim_{x_i\to\infty} U^i_i(x_i,x_j)\le 0$. In addition, $C(x_i)$ is strictly increasing and convex (i.e., $C'(x_i)>0$ and $C''(x_i)\ge 0$) and satisfies $C(0)=0$ and $C'(0)<U^i_i(0,x_j)$.

The agents are strategically interdependent through their efforts as follows. Agent i's benefit decreases as the other agent j makes more effort (i.e., $U^i_j(x_i,x_j)<0$), which is interpreted as an agent's effort having a negative externality on the other agent's benefit. The marginal benefit of agent i decreases or is maintained as agent j makes more effort (i.e., $U^i_{ij}(x_i,x_j)\le 0$).[2]

In the study, we are interested in the Nash equilibrium for a situation where agents decide their efforts (x_i,x_j) simultaneously, given that the subsidy rate s is determined. In particular, we focus on a symmetric equilibrium in which the

[1]The aggregate welfare can be interpreted as social welfare for the society consisting of the agents and the social planner. We measure the benefits and costs of the agents using a monetary unit. The monetary transfers through the subsidies are offset in determining aggregate welfare. In Section 3, we introduce some applications of our model, where social welfare can be defined by considering not only the beneficiaries of the subsidy but also other economic agents. For example, when firms are subsidized in an oligopoly, it is reasonable to consider consumer surplus as well as firms' profits in social welfare. In the case of subsidizing election campaigns for political parties, social welfare may include the welfare of voters.

[2]This implies that the agents' efforts are strategic substitutes.

agents make the same effort. Given the subsidy rate s, we can denote $\chi(s)$ as a symmetric equilibrium, such that each agent i chooses $x_i = \chi(s)$. From the first-order necessary condition for maximizing $V^i(x_i, x_j; s)$ with respect to x_i, $\chi(s)$ has to satisfy

$$U_i^i(\chi(s), \chi(s)) = (1-s)C'(\chi(s)). \tag{1}$$

The assumptions on $U^i(\cdot)$ and $C(\cdot)$ ensure that $\chi(s) > 0$ satisfying (1) exists uniquely and each agent i choosing $\chi(s)$ is a Nash equilibrium.

Applying the implicit function theorem to (1), the assumptions on $U^i(\cdot)$ and $C(\cdot)$ imply that, for any s,[3]

$$\chi'(s) = \frac{C'(\chi(s))}{(1-s)C''(\chi(s)) - (U_{ii}^i(\chi(s), \chi(s)) + U_{ij}^i(\chi(s), \chi(s)))} > 0. \tag{2}$$

This means that agents increase their efforts as the subsidy rate increases. In other words, subsidies are effective in encouraging agents to exert more effort.

Subsidies are generally believed to benefit agents by reducing the cost of their effort. However, Proposition 1 shows that this belief is not always true. Let $\overline{V}^i(s) = V^i(\chi(s), \chi(s); s)$ be agent i's equilibrium payoff when the subsidy rate is s.

Proposition 1. *The equilibrium payoff* $\overline{V}^i(s)$ *of each agent i decreases in s if and only if*

$$C(\chi(s)) \leq -U_j^i(\chi(s), \chi(s))\chi'(s). \tag{3}$$

Proof. The result directly follows from

$$\begin{aligned} \frac{d\overline{V}^i(s)}{ds} &= \left(U_i^i(\chi(s), \chi(s)) + U_j^i(\chi(s), \chi(s)) - (1-s)C'(\chi(s))\right)\chi'(s) + C(\chi(s)) \\ &= U_j^i(\chi(s), \chi(s))\chi'(s) + C(\chi(s)), \end{aligned}$$

where the second equality holds because of (1). □

Proposition 1 provides a condition under which agents become worse off as the subsidy to encourage their efforts increases. Indeed, an increase in the subsidy has the following effects on agent i's payoff. First, the direct positive effect of subsidy on reducing agent i's costs. The second and third effects are through agent i's efforts; specifically, an increase in subsidy induces agent i to

[3] Note that these assumptions are stronger than required for $\chi'(s) > 0$. Subsections 3.2 and 3.3 provide examples in which $U_{ij}^i(x_i, x_j) \leq 0$ is not satisfied but $\chi'(s) > 0$ holds.

make more effort, having a positive effect on one's payoff by increasing own benefit, and a negative effect by increasing own effort cost. The fourth effect is the negative effect through the other agent's effort; an increase in subsidy induces agent j to make more effort, causing a negative effect on agent i's benefit. The second and third effects are offset by agent i's payoff maximization. Thus, the first and fourth effects determine whether subsidy has a positive or negative effect on agent i's payoff. If the first effect is smaller than the last effect, the subsidy is not beneficial to the agents.

Proposition 1 states that the subsidy can improve the agents' payoffs if (3) is not satisfied. However, since the subsidy provided by the social planner is a cost in the social aspect, it may deteriorate aggregate welfare even when it improves the agents' payoffs. Proposition 2 shows that the subsidy always has a negative effect on aggregate welfare. Let $\overline{W}(s) = W(\chi(s), \chi(s))$ be aggregate welfare in the equilibrium when the subsidy rate is s.

Proposition 2. *The aggregate welfare $\overline{W}(s)$ in the equilibrium is decreasing in s.*

Proof. Under the assumptions of $U^i_j(x_i, x_j) < 0$ and $C'(x_i) > 0$, (1) and (2) imply that

$$\begin{aligned}\frac{d\overline{W}(s)}{ds} &= \Big(U^i_i(\chi(s),\chi(s)) + U^i_j(\chi(s),\chi(s)) + U^j_j(\chi(s),\chi(s)) \\ &\quad + U^j_i(\chi(s),\chi(s)) - C'(\chi(s)) - C'(\chi(s))\Big)\,\chi'(s) \\ &= \Big(U^i_j(\chi(s),\chi(s)) + U^j_i(\chi(s),\chi(s)) - 2sC'(\chi(s))\Big)\,\chi'(s) < 0.\end{aligned} \tag{4}$$

holds for any $s \in [0,1]$. □

Proposition 2 states that the greater the subsidy to encourage agents to make an effort, the lower the aggregate welfare. Since agents' efforts have negative effects on each other's payoff, they already make more efforts without subsidy than desirable levels in terms of aggregate welfare. Thus, the subsidy reduces aggregate welfare by encouraging agents to make even more effort, moving them further away from the desirable levels. Proposition 2 also implies that aggregate welfare is maximized when the subsidy is not provided.

3. EXAMPLES

3.1. R&D RACING UNDER COURNOT COMPETITION

An example of our model can be found in Oh and Cho (2023), which investigates the situation in which two firms can reduce their costs through R&D before engaging in Cournot competition.[4] Specifically, each firm i can reduce its marginal cost c into $c_i = c - x_i$ where $x_i \in [0,c]$ can be interpreted as its R&D. R&D is costly, and the R&D cost for firm i is $C(x_i) = \frac{1}{2} r x_i^2$, where $r > 0$ is large enough for the equilibrium to be obtained as an interior solution. The decision procedure consists of two stages. In Stage 1, the firms simultaneously choose their R&D (x_i, x_j) (or, (c_i, c_j)). In Stage 2, they simultaneously choose their outputs (q_i, q_j). The government can provide subsidies to the firms, which reduce their R&D costs. The market demand is linearly given as $p = 1 - Q$.

Given that the firms choose (x_i, x_j) in Stage 1, they choose their outputs (q_i^*, q_j^*) in Stage 2 as a Nash equilibrium to maximize their profits: for each i,

$$U^i(q_i, q_j) = (1 - q_i - q_j)q_i - (c - x_i)q_i.$$

That is, for each i,

$$q_i^* = \frac{1}{3}(1 - c + 2x_i - x_j). \tag{5}$$

Given that the firms choose their outputs (q_i^*, q_j^*) as in (5), we can determine the firms' R&D decisions (x_i^*, x_j^*) in Stage 1 by considering each firm i's payoff as

$$\begin{aligned} V^i(x_i, x_j; s) &= U^i(q_i^*, q_j^*) - (1 - s)C(x_i) \qquad (6) \\ &= \frac{1}{9}(1 - c + 2x_i - x_j)^2 - \frac{1}{2}(1 - s) r x_i^2, \end{aligned}$$

where s is the subsidy rate. For the strategic form game where each firm i's payoff is $V^i(x_i, x_j; s)$ in (6), the symmetric Nash equilibrium is such that each firm i chooses

$$x_i^* = \chi(s) = \frac{4(1 - c)}{9r(1 - s) - 4}. \tag{7}$$

$\chi(s)$ in (7) increases in s (i.e., $\chi(s) > 0$), which means that R&D subsidy is effective in encouraging firms to invest more in R&D.

[4] Oh and Cho (2023), which is written in Korean, analyse the effect of R&D subsidy to firms in a Cournot competition. In particular, they focus on the equilibrium when firms can or cannot observe others' decisions on R&D investments.

Plugging (7) into (6), we can see that, given the subsidy rate s, each firm i's equilibrium payoff is

$$\overline{V}^i(s) = V^i(x_i^*, x_j^*; s) = \frac{r(1-c)^2(1-s)(9r(1-s)-8)}{(9r(1-s)-4)^2}.$$

Note that

$$\frac{d\overline{V}^i(s)}{ds} = -\frac{32r(1-c)^2}{(9r(1-s)-4)^3} \begin{cases} <0 & \text{for } s < \dfrac{9r-4}{9r} \\ >0 & \text{for } s > \dfrac{9r-4}{9r}, \end{cases}$$

which implies that R&D subsidy is not always beneficial to firms. Each firm i's payoff $\overline{V}^i(s)$ in the equilibrium decreases in s when s is low and increases in s when s is high. Although $\overline{V}^i(s)$ increases at a high s, under the assumption that r is sufficiently high, $\overline{V}^i(s)$ is maximized at $s^* = 0$.[5] Thus, in this model, if the R&D cost (measured by r) is sufficiently high, the R&D subsidy is not beneficial to firms.

Oh and Cho (2023) define social welfare as the sum of the firm's payoffs and consumer surplus minus the government's expenditure on R&D subsidy, which is the sum of consumer surplus and the aggregate welfare in Section 2. Then, they show that social welfare is maximized when there is no R&D subsidy (i.e., $s = 0$). They also show that as the subsidy rate s increases from 0, the social welfare in the equilibrium decreases, and that social welfare increases in s after s exceeds a certain level.[6]

3.2. LOCAL SUBSIDIES UNDER NEGATIVE EXTERNALITY

Another example of our model is the subsidies to local governments that make policy efforts to revitalize the local economy. The expenditure of a local government to stimulate the local economy may cause a negative externality to other regions. For instance, if a local government improves accessibility to its lo-

[5]Since $\overline{V}^i(s)$ is decreasing in low s and increasing in high s, this can be verified by confirming $\overline{V}^i(0) > \overline{V}^i(1)$.

[6]It should be noted that they do not claim that R&D subsidies are undesirable for social welfare. They recognize the R&D spillover effect which provides a strong justification for the subsidies to encourage R&D, although it is not reflected in their model. Thus, their results should be interpreted to mean that if the R&D spillover effect is very small, the R&D subsidy may not be desirable for social welfare.

cal market through fiscal expenditure, it may negatively affect merchants in other regions by having the consumers in these regions come to its local merchants.[7]

Consider a situation in which two local governments ($i = 1,2$), each expend $x_i \geq 0$ to revitalize their respective local markets. Local government i's expenditure x_i causes a negative externality to the other region. The central government subsidizes local governments in proportion to $s \in (0,1)$ of their expenditures. Reflecting these features, let

$$V^i(x_i, x_j; s) = R\ln(A + x_i - \beta x_j) - (1-s)x_i$$

for $R > 0$, $A > 0$, and $0 < \beta < 1$ be local government i's payoff when the local governments choose their expenditure (x_i, x_j). Here, $R\ln(A + x_i - \beta x_j)$ is local government i's benefit from expenditures to revitalize the local markets. β measures the degree of negative externality of local government j's expenditure to the other region i. The aggregate welfare has the form of

$$W(x_i, x_j; s) = R\ln(A + x_i - \beta x_j) + R\ln(A + x_j - \beta x_i) - x_i - x_j. \tag{8}$$

Solving local government i's payoff maximization problem given the other local government j's expenditure x_j, we obtain the symmetric Nash equilibrium (x_i^*, x_j^*) that each local government i chooses

$$x_i^* = \chi(s) = \frac{R - A(1-s)}{(1-\beta)(1-s)}. \tag{9}$$

Note that

$$\frac{d\chi(s)}{ds} = \frac{R}{(1-\beta)(1-s)^2} > 0,$$

which means that the central government's subsidy encourages local governments to expend more to revitalize their local markets. In the equilibrium $\chi(s)$ in (9), each local government's payoff is

$$\overline{V}^i(s) = R\ln\left(\frac{R}{1-s}\right) - \frac{R - A(1-s)}{(1-\beta)}, \tag{10}$$

for which

$$\frac{d\overline{V}^i(s)}{ds} = \frac{R(1-\beta) - A(1-s)}{(1-s)(1-\beta)} \begin{cases} < 0 & \text{for } s < 1 - \frac{R}{A}(1-\beta) \\ \geq 0 & \text{for } s \geq 1 - \frac{R}{A}(1-\beta) \end{cases}$$

[7] Hanson and Rohlin (2013) also find such a negative externality by estimating spillover effects from a spatially-targeted redevelopment program (the Federal Empowerment Zone) on neighboring areas.

holds. Here, if $A < R$ and the negative externality β is low enough (i.e., $\beta < 1 - \frac{A}{R}$), an increase in the subsidy rate s at any $s \in (0,1)$ always improves the local government's payoff. If $A < R$ and the negative externality β is high enough (i.e., $\beta > 1 - \frac{A}{R}$), or even if $A > R$, an increase in the subsidy rate s reduces the local government's payoff when s is low and improves the payoff after s exceeds a certain level. We can also see in (10) that $\overline{V}^i(0) = R\ln(R) - \frac{R-A}{1-\beta}$ and $\lim_{s \to 1} \overline{V}^i(s) = \infty$. This implies that subsidy to local governments can negatively affect their payoffs when the subsidy is small, but should have a positive effect on their payoffs when the subsidy is large enough.

Plugging $\chi(s)$ into (8), we obtain the aggregate welfare in the equilibrium as

$$\overline{W}(s) = 2R\ln\left(\frac{R}{1-s}\right) - \frac{2(R - A(1-s))}{(1-\beta)(1-s)}.$$

Since

$$\frac{d\overline{W}(s)}{ds} = -2R\frac{s(1-\beta)+\beta}{(1-\beta)(1-s)^2} < 0,$$

the aggregate welfare in the equilibrium is maximized when the central government does not provide any subsidy and it always decreases as the subsidy rate increases.

3.3. SUBSIDY FOR ELECTION CAMPAIGNS

Many countries subsidize election expenditures for political parties.[8] Generally, the more effort a party puts into its election campaign, the higher its probability of winning the election and the lower the probability of other parties winning. For example, consider a situation in which parties 1 and 2 compete to win an election. Let $x_i \geq 0$ be party i's effort level in the election campaign. The probability of party i winning the election is assumed to depend on the relative ratios of their efforts and represented as a function $p\left(\frac{x_i}{x_i+x_j}\right)$ that is strictly increasing (i.e., $p'(\cdot) > 0$) and satisfies $p(0) = 0$ and $p\left(\frac{x_i}{x_i+x_j}\right) + p\left(\frac{x_j}{x_i+x_j}\right) = 1$ for any (x_i, x_j). Each party i gains $R > 0$ if it wins the election and 0 otherwise, and has to pay a cost $C(x_i) = rx_i^k$ with $r > 0$ and $k \geq 1$ when it makes an effort of x_i in the election campaign. The government subsidizes a fraction $s \in (0,1)$ of this

[8] For the studies on election campaigns, see Myerson (1993), Boyer *et al.* (2017), and Hwang and Koh (2023).

cost. Thus, given the subsidy rate s, party i's (expected) payoff is

$$V^i(x_i, x_j; s) = p\left(\frac{x_i}{x_i + x_j}\right)R - (1-s)rx_i^k$$

when the parties choose their efforts (x_i, x_j).

Let $x^* = \chi(s)$ be the symmetric Nash equilibrium for the parties. Then, $x_i = \chi(s) > 0$ has to satisfy the first order necessary condition

$$\frac{\partial V^i(x_i, x_j; s)}{\partial x_i} = \frac{x_j}{(x_i + x_j)^2}p'\left(\frac{x_i}{x_i + x_j}\right)R - (1-s)krx_i^{k-1} = 0$$

to maximize $V^i(x_i, x_j; s)$, given that party j chooses $x_j = \chi(s)$. Thus, we have

$$\chi(s) = \left(\frac{R}{4(1-s)kr}p'\left(\frac{1}{2}\right)\right)^{\frac{1}{k}}. \tag{11}$$

Assuming that R is high enough, $x_i = \chi(s)$ in (11) maximizes $V^i(x_i, x_j; s)$ given party j chooses $x_j = \chi(s)$.[9] Thus, each party i choosing $x_i = \chi(s)$ in (11) for its effort in the election campaign constitutes a symmetric Nash equilibrium.

From (11), it is obvious that $\chi(s)$ is increasing in $s \in (0,1)$ (i.e., $\chi'(s) > 0$), which means that the subsidy for the costs in the election campaign induces the parties to spend more in the campaign. However, since each party i's payoff in the equilibrium is

$$\overline{V}^i(s) = V^i(\chi(s), \chi(s); s) = p\left(\frac{1}{2}\right)R - \frac{1}{4k}p'\left(\frac{1}{2}\right)R, \tag{12}$$

the subsidy for the election campaign does not affect the parties' payoffs (i.e., $\frac{d\overline{V}^i(s)}{ds} = 0$).[10] This is intuitively obvious because the subsidy provided to both parties does not change their effort levels and probability of winning. In addition, each party incurs a cost in the election campaign, so that its marginal spending (the cost compensated by the subsidy) is equalized to its marginal expected gain from the effort. Thus, the actual spending of each party does not depend on the subsidy rate s.

[9]This can be established by confirming $V^i(\chi(s), \chi(s); s) > V^i(0, \chi(s); s)$ and $\lim\limits_{x_i \to \infty} V^i(x_i, \chi(s); s) = -\infty$.

[10]It should be noted that, in general, the subsidy for election expenditure is aimed at preventing the right to be elected from being restricted for economic reasons rather than improving the welfare of political parties.

In this model, the aggregate welfare is the sum of the parties' payoffs minus the subsidy:

$$W(x_i, x_j; s) = p\left(\frac{x_i}{x_i + x_j}\right) R + p\left(\frac{x_j}{x_j + x_i}\right) R - r x_i^k - r x_j^k.$$

In the equilibrium, the aggregate welfare is

$$\overline{W}(s) = W(\chi(s), \chi(s); s) = 2p\left(\frac{1}{2}\right) R - \frac{1}{2(1-s)k} p'\left(\frac{1}{2}\right) R,$$

which decreases in $s \in (0,1)$ (i.e., $\frac{d\overline{W}(s)}{ds} < 0$).

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