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ON THE PRIVATE AND SOCIAL VALUE
OF PUBLIC GOOD INPUTS

by

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ABSTRACT

The paper generalizes the conditions in a competitive market by which producers and consumers benefit from investments in public good inputs (such as research and development) under alternative cost-sharing arrangements. When consumers finance the public good, an oversupply may result when either the producers or the consumers control the level of the investment. In these situations, the group not controlling the quantity of input invested will likely be worse off compared to a situation of zero investment. When producers finance and control the level of investment, the supply is less than the social optimum but social welfare will be greater than if no investment was undertaken.

ON THE PRIVATE AND SOCIAL VALUE OF PUBLIC GOOD INPUTS

I. INTRODUCTION

Competitive industries often employ cost-reducing inputs that exhibit "public good" characteristics. Several important examples include direct technological inputs (research and development--R & D), the production and distribution of knowledge (information and education), and transportation facilities (roads and terminals).

A standard conclusion is that an underinvestment of such public good inputs will occur under perfect competition since individual firms cannot appropriate the entire economic benefit [Arrow, 1962]. The suboptimal allocation of resources under competition may result in the emergence of other institutional arrangements to provide the public good input. For example, the government may provide the public good directly with financing from general tax revenues. On the other hand, competitive firms may "collude" to finance the provision of the public good jointly leading to collective action in the input market while maintaining competition in the output market.

It is not evident that any of these alternative arrangements will lead to a social optimal allocation of resources or that they even improve aggregate social welfare relative to the competitive market outcome. "Collusion" by producers to provide the public good input themselves will result in a private rather than a social maximum of economic welfare. Similarly, in the case where the government provides the public good directly, politicians may weigh unevenly the welfare of different groups in society or may even be "captured" by a particular group in maximizing the latter's welfare [Posner, 1974; Downs, 1957; Peltzman, 1976; and Stigler, 1971]. The allocation of resources in a competitive market will differ under alternative institutional situations and cost-sharing arrangements. Thus, the extent and conditions by which the private and social welfare differ becomes an important consideration and should be incorporated in economic welfare analysis.

Agriculture is an example of an industry with extensive use of public good inputs. In many instances, governments both provide and finance many forms of agricultural research, development, and education. However, the rate of investment in public research in agriculture is not necessarily socially optimal, and many empirical studies for the American case indicate that there is a significant underinvestment in public research for agriculture [Griliches, 1958; Ruttan, 1980; Schultz, 1971].[1] There are instances where agricultural research and development is being financed and managed by growers' associations (using marketing orders and agreements as a legal vehicle to overcome antitrust problems), and it is very likely that it will be suboptimal for society but optimal for the growers.

Studies on the economics of public good inputs have focused mostly on the impacts of imperfect market structure on R & D performance [Kamien and Schwartz, 1975].[2] Little attention has been given to conceptual analysis of the impact of alternative political situations and institutional arrangements on the provison of public good inputs to competitive industries. This paper will address the latter issues by considering several alternative scenarios. In two of the cases examined, the taxpayers finance the provision of the public good: In one of these, the determination of the quantity of the public good is controlled by consumers and, in the other, it is controlled by producers. These two polar cases set a bound on all possible outcomes whereby the public good is financed by the taxpayer. The third case is when the producers both finance the provision of the public good and determine its quantity. For each of these cases, the resulting level of the public good provided is compared to the social optimum; the welfare of consumers and producers, as well as the welfare of society, is compared to both the social optimal level of the public good and the competitive level involving no government intervention.

II. THE MODEL

The analysis uses a deterministic, static, and partial-equilibrium model of a closed economy with competitive market conditions assumed to prevail. Suppose that consumer preferences are represented by the separable additive utility function $U(q, Z) = U(q) + Z$ where q is the good under consideration and Z is the numeraire good. It is assumed that the marginal utility of consuming q is positive and declining, $U_q > 0$, $U_{qq} < 0$.

The cost function facing the industry, $C(q, E)$, depends on output, q, and public good expenditure, E. It is assumed that the marginal cost of output is positive and increasing ($C_q > 0$, $C_{qq} > 0$); that an increase in public good expenditures reduces cost as long as the expenditures are below a saturation level, $E^Z(q)$, i.e., $C_E < 0$, $0 \leq E < E^Z(q)$, $E^Z(q) = 0$; and that cost is convex in both E and q ($C_{EE} \geq 0$, $C_{EE}\, C_{qq} - C_{qE} > 0$). It is also assumed that the marginal impact of the public good on cost is nonincreasing with the level of operation ($C_{Eq} \leq 0$). If the public good affects only the fixed cost of production, then $C_{qE} = 0$; if an increase in E reduces variable cost, then $C_{qE} < 0$. To consider alternative scenarios on the incidence of burden of public good expenditures, let α denote the share of the public good expenditure paid by consumers. If the government provides the public good using the taxpayers' money obtained from consumers, then $\alpha = 1$. If, however, the firms in the industry collude and finance the public good provision by themselves, then $\alpha = 0$. Assume that individual consumers and producers consider α and E as given in determining their consumption and production choices. Thus, consumers would choose q to maximize $U(q, Y - pq - \alpha E)$ where p is output price and Y is income, and producers would choose q to maximize $pq - C(q, E) - E(1 - \alpha)$. The resulting demand and supply relationships are, respectively, $q = D(p) \equiv U_q^{-1}(p)$ and $q = S(p, E) \equiv C_q^{-1}(p, E)$ where D is demand and S is supply. Equilibrium in the product market is obtained when marginal cost equals marginal utility, $C_q = U_q$; thus, equilibrium price and quantities are functions of the public good expenditure and are denoted by $q^*(E)$ and $p^*(E)$.

The marginal effect of an increase in public good expenditures on output is obtained by total differentiation of the first-order condition to yield

$$q_E^* = \frac{C_{qE}}{U_{qq} - C_{qq}} = \frac{C_{qE}\, \eta^S \eta^D \cdot q^*}{p(\eta^S - \eta^D)}, \tag{1}$$

where $\eta^S \equiv S_p \cdot p/q = p/(C_{qq} \cdot q)$ denotes price elasticity of supply and $\eta^D = D_p \cdot p/q = p/(U_{qq} \cdot q)$ denotes price elasticity of demand. Using equation (1) and the total differentiation of the consumer decision rule, $U_q = p$, yields an expression describing the marginal impact of change in public good expenditures on output price,

$$p_E^* = \frac{C_{qE}}{1 - \eta^D/\eta^S}. \tag{2}$$

The magnitude of the change in price depends on the magnitude of the marginal impact of public good expenditures on marginal cost ($|C_{qE}|$); thus, a larger $|C_{qE}|$ results in a greater horizontal shift in supply, a greater increase in output, and a greater reduction in output price. An increase in public good expenditure will have a stronger output price effect and a weaker output effect as the elasticity of demand is smaller (in absolute value) and a smaller price and output effect as supply is more inelastic.

Introducing q*(E) and p*(E) into the profit and utility functions yields equilibrium utility (U) and profit (π) as functions of the public good expenditure, namely,

$$U^*(E) \equiv U[q^*(E)] + Y - p^*(E)\, q^*(E) - \alpha E$$

and

$$\pi^*(E) \equiv p^*(E)\, q^*(E) - C[q^*(E), E] - (1 - \alpha)\, E.$$

Differentiation of these functions with respect to the public good expenditure, using $C_q = U_q$ and equations (1) and (2), yields

$$(3) \qquad U_E^* = -q^*\, p_E^* - \alpha = -C_E \frac{\varepsilon^q}{1 - \eta^D/\eta^S} - \alpha$$

$$(4) \qquad \pi_E^* = -C_E + q^*\, p_E^E - (1 - \alpha) = -C_E \left[1 - \frac{\varepsilon^q}{1 - \eta^D/\eta^S}\right] - 1 - \alpha$$

where $\varepsilon^q = C_{qE} \cdot q/C_E$ is the output elasticity of the marginal impact of the public good on cost. This elasticity, ε^q, is nonnegative; it equals zero when the public good affects the fixed cost of production. However, it may be larger than 1 when the public good affects the variable cost. For example, if the cost function is multiplicative and separable in q and E, $C(q, E) = h(q)\, q(E)$, then $\varepsilon^q = h_q\, q/h(q) > 1$ by the convexity of the cost function. If the cost function is additive in q and E, $C(q, E) = h(q) - q(E)$; then $\varepsilon^q = 0$.

A marginal increase in the public good input expenditure has four effects. It has a cost-reducing effect measured by $-C_E$; a price-reducing effect equal to the marginal decline in price times the quantity, $q^* p^*_E$; and a consumers' expenditure effect which equals α and a producers' expenditure effect of $1 - \alpha$. Equation (3) suggests that the marginal impact on consumers of an increase in the public good input is the difference between the price-reduction effect, $q^* p^*_E$, and the consumers' expenditure effect, α. Equation (4) suggests that the marginal impact on the producers' welfare of an increase in the public good is the difference between the cost-reducing effect and the sum of the price-reducing effect and the producers' expenditure effect.

Obviously, when producers control the provision of this public good input, $\pi^*(E)$ is maximized, while $U^*(E)$ is maximized when consumers have the power or influence to determine the level of E. The welfare evaluation of outcomes under alternative institutional arrangements is obtained by using the total surplus function, $W^*(E) \equiv U^*(E) + \pi^*(E)$. This is an appropriate welfare standard since, given resources and technology [Y and $C(\cdot,\cdot)$], utility from consumption is $W(q, E) = U(q) + Y - E - C(q, E)$. For each E, $W(q, E)$ is maximized when $C_q = U_q$; hence, q behaves according to $q^*(E)$. Welfare as a function of E is given by:

$$W(q^*, E) = U(q^*) - \alpha E + p(q^*)\, q^* - p(q^*)\, q^* - C(q^*, E) - (1 - \alpha)\, E$$
$$= U^*(E) + \pi^*(E).$$

Differentiation of the welfare criteria function yields

(5) $$W_E^* = -C_E - 1.$$

Social welfare is increasing with the public good expenditure as long as the marginal reduction in cost associated with the public good expenditures exceeds the marginal increase in the expenditures. Total differentiation of (5) and substitution for q_E^* using (1) yields

$$W_{EE}^* = \frac{[C_{EE}\,C_{qq} - C_{qE}^2] - C_{EE}\,U_{qq}}{U_{qq} - C_{qq}}.$$

The cost and utility function assumptions assure that W*(E) is concave ($W_{EE}^* < 0$).

The optimal public good expenditure is zero if the introduction of an infinitesimal quantity of the public good results in a cost-reduction effect that is smaller than the public expenditure. Otherwise, it occurs at a level where the marginal cost-reduction effect associated with the public good equals the marginal expenditure, i.e.,

(6)
$$\begin{aligned} E^* &= 0 \qquad \text{if at } E = 0,\ -C_E < 1 \\ E^* &> 0 \qquad \text{if at } E^*,\ -C_E = 1. \end{aligned}$$

III. INCIDENCE OF COST/BENEFITS UNDER ALTERNATIVE ALLOCATION MECHANISMS

This section examines the implications of three alternative allocation mechanisms and compares them to (a) the competitive outcome without provision of the public good and (b) the social optimum. The cases considered are:

1. The government finances the public good via a consumer income tax, and producers determine or influence its level. In this case, $\alpha = 1$, and E is determined by maximizing $\pi^*(E)$. This situation has the government providing

the public good while the administrators in charge are being captured by producers in the industry.

2. Consumers finance the public good through generalized taxation but determine its level. In this case, $\alpha = 1$ and E is determined by maximizing $U^*(E)$. This is the case where government administrators are captured by consumer groups in allocating the level of public good inputs.

3. Producers finance the public good and determine its level. In this case $\alpha = 0$, and E is determined by maximizing $\pi^*(E)$. This situation results from collective action by producers in providing the public good.

The following subsections will analyze the incidence of economic costs/benefits in detail for each of these cost-sharing and allocation mechanisms.

A. Consumers Finance the Public Good; Producers Determine its Quantity

Let E^1 denote the public good expenditure in this case. It is nonnegative and maximizes the producers' profit for $\alpha = 1$. In this case the marginal impact of an increase in the public good expenditure on the producers' profit is the difference between the cost-reduction effect and the price-reduction effect. Using equation (4),

$$\pi^*_E = -C_E + q^* p^*_E = -C_E \left[1 - \frac{\varepsilon^q}{1 - \eta^D/\eta^S}\right] . \tag{7}$$

Assuming concavity of profit in E and q, equation (7) implies there are three possible solutions for E^1:

$$E^1 = 0 \qquad \text{if } 1 - \eta^D/\eta^S < \varepsilon^q \text{ for } E = 0$$

$$(8) \qquad 0 \leq E^1 \leq E^Z(q*) \qquad \text{if } 1 - \eta^D/\eta^S = \varepsilon^q \text{ for } E = E^1$$

$$E^1 = E^Z(q*) \qquad \text{if } 1 - \eta^D/\eta^S > \varepsilon^q \text{ for } E = E^Z(q*)$$

where $E^Z(q*)$ denotes the saturation level of the public good expenditures associated with the market-clearing output level.

Equation (8) suggests that the public good will not be provided if the price-reduction effect associated with the public good is larger than the cost-reduction effect even for small levels of E. If the public good is provided, its exact quantity is determined at a level where the marginal price-reduction effect ($q* \, p^*_E$) equals the marginal cost-reduction effect ($-C_E$). This level may be the public good saturation level if, for smaller levels of public good expenditures, the marginal cost effect dominates the marginal price effect. Equation (8) also indicates that the <u>public good expenditures increase as the elasticity of demand is increasing (in absolute value), the elasticity of supply is decreasing, and the output elasticity of the marginal impact of the public good on cost is decreasing</u>. Thus, when producers control the public good provision, more money will be spent on the public good when (1) E has a stronger impact in reducing fixed costs as opposed to variable costs, (2) the industry is facing a more elastic demand curve, and (3) the industry has rigid production coefficients rather than the flexibility to adjust its production capacity in response to changes in economic conditions.

B. <u>Consumers Finance the Public Good and Determine its Quantity</u>

Let E^2 denote the public good expenditure in this case. It is nonnegative and maximizes consumers' welfare for $\alpha = 1$. Using (3), in this case the marginal impact of an increase in public expenditures on consumer welfare is the difference between the price-reduction effect of a marginal increase in public good expenditures and the expenditure itself, i.e.,

$$U_E^* = -q^* \, p_E^* - 1 = -C_E \frac{\varepsilon^q}{1 - \eta^D/\eta^S} - 1. \tag{9}$$

Assuming concavity of consumer welfare in E, equation (9) implies that there are two solutions for E^2. The public good will not be provided if the price-reduction effect associated with the introduction of an infinitesimal quantity of the public good is smaller than the expenditure it involves ($E^2 = 0$ if $-q^* \, p_E < 1$ at $E = 0$). Alternatively, if the public good is provided, the optimal quantity is determined by equating the marginal price-reducing effect with the marginal expenditure (at $E^2 - q^* \, p_E^* = 1$). From (9), the behavior of the optimum outcome can be rewritten as:

$$E^2 = 0 \qquad \text{if } -C_E < \frac{1 - \eta^D/\eta^S}{\varepsilon^q} \text{ at } E = 0$$

(10)

$$0 \leq E_2^2 < E^Z(q^*) \qquad \text{if } -C_E = \frac{1 - \eta^D/\eta^S}{\varepsilon^q} \text{ at } E = E^2.$$

Since $C_{EE} < 0$, <u>equation (10) indicates that public good expenditures increase as the elasticity of demand is decreasing the elasticity of supply is</u>

increasing, and the output elasticity of the marginal impact of public good on cost is increasing. Thus, consumers will not support any level of public good expenditure if the demand is infinitely elastic, if the supply is inelastic, or if the public good affects fixed cost and not variable cost. On the other hand, when demand is inelastic and the public good expenditure has a strong impact on variable cost (and, thus, shifts supply to the right), a relatively large volume of public good expenditures will be supported by consumers.

C. Comparison of Consumer, Producer, and Social Optima: Consumers Finance the Public Good

Using equations (5), (8), and (10) and assuming that three welfare functions, $W^*(E)$, $U^*(E)$, and $\pi^*(E)$, are concave in E,[3] one can compare E^1, E^2, and E^* under alternative conditions. The results of these comparisons are given in Table I. The optimum levels of the public good for either producers, consumers, or society is zero if $-C_E < -q^* \, p_E^* < 1$ (Condition a); and all are positive if $-C_E > -q^* \, p_E^* > 1$ (Condition f). For the latter condition, the social optimum is less than the producer optimum if $-C_E < 1$ and less than the consumer optimum if $-C_E > 1$.

Some of the results summarized in Table I are depicted graphically in Figure I. The analysis uses the functions, $\tilde{\pi}(E) = \pi^*(E) - \pi^*(0)$, $\tilde{U}(E) = U^*(E) - U^*(0)$, and $\tilde{W}(E) = W^*(E) - W(0)$ which denote welfare gains to the groups relative to competition whereby no public goods are provided. Figure Ia depicts possible scenarios with $U_E^*(0) < 0$ for all levels of E. This implies $\tilde{U}(E) < 0$, and the concavity of U^* ensures that $\tilde{U}_E(E) < 0$. Obviously, $E^2 = 0$ in this case. If both the producers' and social optima are positive (as in the case where they are E_1^1 and E_1^* with welfare functions $\tilde{\pi}^1$ and $\tilde{W}^1$ respectively),

TABLE I

A Comparison of Consumer, Producer, and Social Optima
When Consumers Finance the Public Good Input

Condition	Public Good Expenditure			
	E^1	E^2	E^*	
a	0	0	0	if at $E = 0$, $-C_E < -q^*P_E^* < 1$
b	>0	0	0	if at $E = 0$, $-q^*P_E^* < -C_E < 1$
c	0	>0	0	if at $E = 0$, $-C_E < 1 < -q^*P_E^*$
d	>E*	0	>0	if at $E = 0$, $-C_E > 1 > -q^*P_E^*$
e	0	>E*	>0	if at $E = 0$, $-q^*P_E^* > 1 > -C_E$
f	>0	>0	>0	if at $E = 0$, $1 < -q^*P_E^* < -C_E$
f(i)	>E*	>0	$>E^2$	if at E^1, $-C_E < 1$
f(ii)	>0	>E*	$>E^1$	if at E^1, $-C_E > 1$

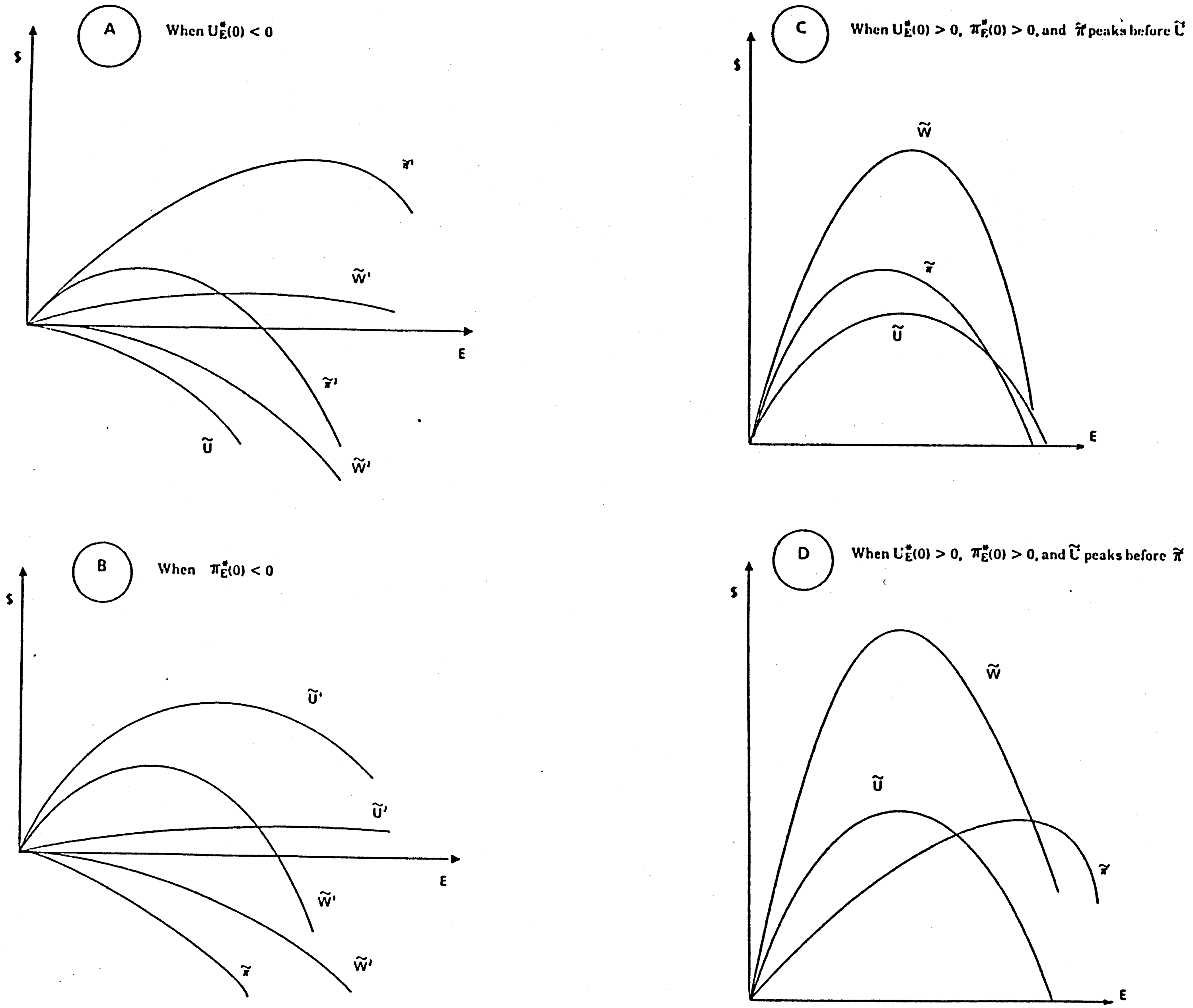

Figure 1

The Effect of Public Good Expenditures on Producer, Consumer, and Social Welfare then $\tilde{\pi}_E(0) > 0$ and $\tilde{W}_E(0) > 0$. Note that $\tilde{\pi}(E)$ is above $\tilde{W}(E)$ when both are positive since $\tilde{W}(E) = \tilde{\pi}(E) + \tilde{U}(E)$. At the producers' optimum, E_1^1, the slopes of both $\tilde{W}(E)$ and $\tilde{U}(E)$ are identical since $\tilde{\pi}_E + \tilde{U}_E = \tilde{W}_E$ and $\tilde{\pi}_E(E^1) = 0$. Since $\tilde{U}_E(E^1) < 0$ and $\tilde{W}_E(E^1) < 0$, it follows that the producers' optimum is larger than the social optimum in Figure IA. This is captured by Condition d in Table I. Note that social welfare at the producers' optimum may be smaller than in the case of no provision for public good [$\tilde{W}(E^1)$ may be negative] and, thus, society as a whole may lose from the provision of the public good under producers' control in cases when $-C_E > 1 > -q^* p_E$ at $E = 0$.

Another scenario depicted in Figure IA is where the social welfare curve is $\tilde{W}^2$, producers' welfare is $\tilde{\pi}^2$, and consumers' welfare is $\tilde{U}$. Since $\tilde{W}^2(E) < 0$, the social optimum is at $E = 0$ and the producers' optimum is at E_2^2, with society obviously losing from the introduction of the public good. This case is summarized by Condition b in Table I.

Figure IB depicts scenarios with $\pi_E^*(0) < 0$. Condition e in Table I applies to the case when the welfare functions are $\tilde{\pi}$, $\tilde{W}^1$, and $\tilde{U}^1$, while the case of Condition c occurs when the welfare functions are $\tilde{\pi}$, $\tilde{U}^2$, and $\tilde{W}^2$.

Figures IC and ID depict scenarios where both $U_E^*(0)$ and $\pi_E^*(0)$ are positive. Here, for small E's, all functions are increasing; and, provided they increase, $\tilde{W}$ is larger than both $\tilde{U}$ and $\tilde{\pi}$. In the case where producers' welfare peaks first (Figure IC), the consumers' welfare is increasing at E^1 and $\tilde{U}(\tilde{E}^1) > 0$. Thus, Figure IC indicates that the producers and consumers are better off when the amount of public good provided under the producers' control is positive but smaller than the social optimum. Figure ID corresponds to the case of Condition f(i) in Table I. Here, the social welfare curve peaks before the producers' welfare curve ($E^1 > E^*$). In such cases, consumers' welfare under producers' control of the public good provision may be larger (as depicted here) or smaller than under competition with no public good provision. Figure ID also suggests that both the producers' and consumers' welfare will improve when consumers control the public good provision if $E^2 < E^*$. If $E^2 > E^*$, producers may lose from the provision of public good when it is under the consumers' control.

Since the price-reduction effect embodies the impact of the values of η^D, η^S, and ε^q, the cost-reducing effect is, in essence, a measure of the productivity of the public good. The scenarios developed above can be linked to different orders of magnitude of demand elasticity and public good productivity (mostly at $E = 0$) given η^S and ε^q. Such an analysis suggests that, when the productivity of public good is low ($-C_E < 1$) but the elasticity of demand is sufficiently high, the public good will be provided under the producers' control even though consumers and society will lose in welfare. Actually, when demand is infinitely elastic ($\eta^D = 0$) and $-C_E < 1$, the gap between the producers' optimum and consumers' optimum of the public good is at an extreme [$E^* = 0$, $E^1 = E^Z(q^*)$].

When public good productivity is low and demand elasticity is low, one may encounter situations when the social optimum and the producers' optimum are the same and no public good is provided. In such situations (as in Condition c of Table I), it may be optimal to provide a substantial amount of public good from the consumers' perspective.

When public good productivity is high but demand is sufficiently elastic, the social optimum will require a provision of a certain level of public good;

but the producers' interest will require a higher level. Thus, under producers' control of the public good, consumers may actually lose compared to nonintervention (Condition d in Table I). If, however, public good productivity is sufficiently high and demand elasticity is sufficiently low, a situation may arise where both consumers and producers benefit from the introduction of public good (Condition f in Table I). One such situation is Condition f(ii) in Table I where the producers' optimum of public good levels is smaller than the social optimum.

The results of Table I shed some light on the tendency to underinvest in public research and development in U. S. agriculture. Since the demand elasticity for agricultural products is notoriously low and the productivity of public R & D is high [Schultz, 1953], the tendency to underinvest in public agricultural R & D is consistent only with Condition f(ii) in Table I. That suggests that the control of R & D in agriculture has been strongly influenced by producers. Moreover, Condition f(ii) suggests that, under such a scenario, consumers benefit relative to no intervention; therefore, they do not strongly oppose the producers' control over providing the cost-reducing public good.

D. Producers' Fianance and Determine Public Good Expenditures

Let E^3 denote the public good expenditure in this case. It is nonnegative and maximizes producers' welfare for $\alpha = 0$. Using (4), the marginal impact of an increase in public good expenditures on producers' profit is the difference between the cost-reducing effect and the sum of the price-reducing effect and the marginal increase in the expenditure. That is,

$$(11) \qquad \pi^*_E = -C_E + q^* p^*_E - 1 = -C_E \left[1 - \frac{\varepsilon^q}{1 - \eta^D/\eta^S}\right] - 1.$$

Assuming concavity of profits as a function of E, equation (11) suggests two solutions for E^3:

$$
(12) \qquad
\begin{aligned}
E^3 &= 0 && \text{if } -C_E < -q^* \, p_E^* + 1 \text{ at } E = 0 \\
0 < E^3 &< E^Z(q^*) && \text{if } -C_E = \frac{1}{1 - \dfrac{\varepsilon^q}{1 - \eta^D/\eta^S}} \text{ at } E = E^3 > 0.
\end{aligned}
$$

The public good will not be provided if the price-reduction effect and the expenditure associated with the public good are greater than the cost-reduction effect even for infinitesimally small levels of E. If the public good is provided, its exact quantity is determined at the level where the sum of the marginal price-reduction effect and the marginal expenditure is equal to the marginal cost-reduction effect. As in the case of $\alpha = 0$, the public good expenditures may increase as the elasticity of demand is increasing (in absolute value), the elasticity of supply is decreasing, and the output elasticity of the marginal impact of public good on cost is declining.

Comparing equations (12), (5), and (8), note that the provision of the public good when producers both pay and control the quantity provided cannot exceed the social optimum or the producers' optimum of the public good when consumers pay. Indeed, the likelihood of no public good being provided is greater in the case where the producers both finance and control the provision of the public good compared to the outcome of the other two situations discussed. There is no possibility of an oversupply of the public good when the producers pay; at most, the producers' optimum (when producers pay) can equal the social optimum. The equality of positive E^3 and E^* occurs when demand is infinitely elastic, supply is completely inelastic, or the public good has no effect on variable cost. Note that, in any of these cases, the producers' optimum when consumers pay will be higher than the social optimum and, indeed, will be at the saturation level, $E^Z(q*)$. The social optimum can also be equal to the producers' optimum when producers pay in cases where the public good has a low cost-reducing effect ($-C_E < 1$ at $E = 0$). In these cases, society and the producers will benefit from not producing the public good. Thus, in summary, one finds

$$
\text{(13)} \qquad \begin{aligned} E^3 &= 0 \qquad \text{if } E^* = 0 \\ E^3 &\leq E^* \qquad \text{if } E^* > 0. \end{aligned}
$$

The concavity of W* and the behavior described in (13) are sufficient conditions for <u>social welfare to increase (compared to no intervention) if producers both finance and control the level of the public good investment</u>. Moreover, if U* is concave, the consumer can only benefit from positive levels of the public good when producers control and pay for it. Thus, it seems socially desirable not to prevent "collusion" among or collective action by firms in a competitive industry to provide a cost-reducing public good input.

It is inevitable, however, that the resulting level of the public good investment is less than the social optimum with this divergence being greater in sectors with more inelastic demand curves and more elastic supply curves. Hence, it is not a sufficient condition that a social optimum will be obtained if the government encourages firms to provide the public good themselves by collusive agreements. Indeed, the government would have to intervene and supplement the private levels of the cost-reducing input and even more so with higher supply elasticities or lower demand elasticities. This may lead to a "crowding out" of private investment so that governments would always have to provide or control directly the total expenditure on cost-reducing public good inputs in order for a social optimum to be attained.

IV. CONCLUSIONS

This paper demonstrates that social optimal allocation of a cost-reducing public good input in a competitive industry does not always coincide with the optimum of either consumers or producers. When consumers finance the public good, an oversupply may result when either the producers or consumers control the level of investment. In these situations, the group not in control is likely to be worse off compared to a situation of no public good being provided at all. However, if consumers finance and producers control the public good provision and the quantity provided is smaller than the social optimum, then social, producers', and consumers' welfare are increased relative to the situation of no public good being provided.

When producers control and pay for the provision of the public good, the supply is likely to be smaller than the social optimum and, at most, it will equal the social optimum. Social welfare in such cases will be greater than under a situation of no public good being provided. Moreover, consumers' welfare is likely to improve when producers cooperate collectively to finance and control the provision of a public good input. However, a social undersupply of the public good input will result in such situations.

Governments may be tempted to augment public provision of the public good inputs. Such intervention is facing the risk of curtailing the private provision of the public good input and substituting private financing with public provision with all the resulting equity and political implications.

The analysis delineates the economic factors including characteristics of supply and demand that determine the magnitude and direction of the divergence between social and private benefits (or costs) to investments in public good inputs. The model generalizes the conditions and extent to which producers and consumers benefit from public good investments under alternative cost-sharing arrangements. These results have implications for understanding the observed underinvestment in R & D reported in many rate-of-return studies [Mansfield et al., 1977; Ruttan, 1980; Schultz, 1971]. For example, results in section III.D. show that there is always a social gain from private investment by producers in public good inputs and will always be larger than the benefits accruing to producers. This will occur even though producers organize to provide the producer optimum of the public good input and perfect competition prevails in the output market. Indeed, a priority for further research would be to consider the optimal provision of public good inputs in noncompetitive sectors under alternative political structures and to introduce a game-theoretic framework to solve simultaneously for the political and economic equilibrium.

FOOTNOTES

1. Several studies have generated evidence that political and institutional factors are responsible for this suboptimal allocation of resources in agriculture [Rose-Ackerman and Evenson, 1985; Guttman, 1978; Huffman and Miranowski, 1981].

2. Indeed, the debate in the literature revolves around the Schumpeterian argument that a certain degree of monopoly power over output prices is necessary to provide incentives for the social optimal provision of cost-reducing public good inputs by the private sector [Loury, 1979].

3. Actually, concavity of U^* and π^* is a stronger assumption than most of the following results require. It is sufficient to assume that there is a unique optimal public good level for each group and that, if the marginal impact of public good on the producer welfare (consumer welfare) is negative at $E = 0$, it will be negative at $E > 0$.

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