SOCIAL SUBSIDIES, ENVIRONMENTAL POLLUTION, AND UTILIZATION OF AGRICULTURAL WASTES: AN OREGON EXAMPLE*

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Increased public awareness in recent years regarding environmental pollution has generated concern over the disposal of household, commercial, industrial, animal, and agricultural wastes [7, 12]. In most cases, utilization of these wastes is not feasible because of high recovery costs. The substantial quantities involved often preclude disposal by landfills and their burning contributes to air pollution. One such case is the environmental pollution caused from disposal of grass seed residue by open field burning in Oregon.

Open field burning is the least cost means to dispose of harvest residue[1] and provide essential thermal treatment to destroy disease organisms. An estimated one million tons of residue, on the average, are burned in the Willamette Valley annually creating serious air pollution problems in late summer [5]. A ban on open burning enacted by state law, and effective January 1, 1975, could force major adjustments upon Oregon's grass seed industry.

Historically, grass seed production generates low profit margins relative to other crops and because of soil drainage problems alternative crops have been limited. Incorporation of residue into the soil is not practical because of peculiar soil and weather characteristics and, with exception of annual ryegrass, all of the grasses are perennial species. Commercial development of mobile field sanitizers[2] appears technically feasible, but their use is expected to increase grass seed production costs significantly [8]. As a consequence, it has become increasingly well recognized that commercial utilization of grass seed residue, if economically feasible, could play a crucial role for easing the stress of economic adjustment for Oregon grass seed producers [8].

Technically speaking, the grass residue can be used as a raw material in the manufacture of microbial proteins, plastics, fuel oil, paper and hardboard, and as a source of animal feed [9]. Economic evaluations of the latter two uses indicate that grass residue cannot compete as a raw material in the existing markets because of relatively high costs for its collection, densification, storage, and transportation [2, 16]. This suggests that social subsidies may be necessary if large volumes of residue are to be utilized in commercial channels.

This paper presents and discusses a conceptual framework for the economic and social rationale of subsidies to facilitate commercial utilization of grass residue. A theoretical model of demand and supply relationships in selected residue markets is developed also.

CONCEPTUAL FRAMEWORK

The smoke produced by open field burning of

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[1] The words "residue" and "grass seed residue" are used interchangeably in this paper.

[2] The mobile field sanitizer is a mechanical device developed by the Department of Agricultural Engineering, Oregon State University, to burn harvest residue and stubble in its path within a self-sustaining combustion chamber [3].

grass residue imposes externalities upon the consumers of a "clean" environment. To control externalities, economists traditionally have proposed systems of taxes, effluent charges, and subsidies [2, 19]. Baumol and Oats argue that since it is difficult to measure marginal social damage, determination of optimum taxes (subsidies) to be imposed upon identifiable polluters (pollutees) is rarely feasible [1]. Instead, they suggest an alternative "environmental pricing and standards" approach. While their approach appears to be empirically feasible, if the externality-generating activity involves the use of a common property resource, the question of who should compensate whom remains unanswered. This is particularly true of air pollution caused by open field burning of residue.

Since the question of property rights *per se* is not within the scope of this study, we start with the premise that society in Oregon might be willing to provide a full or partial compensation in the form of subsidy for collection, densification, storage, transportation, etc., of residue. The subsidy could permit residue to compete with alternative raw materials in existing markets as a means for maintaining Oregon's grass seed industry while reducing or perhaps eliminating air pollution.

Types of Subsidies

Commercial utilization of residue as a raw material, among other things, is a function of prices. At present, the relative prices are such that the effective demand for residue is non-existent. A social subsidy paid by the State of Oregon, either to the potential sellers or the potential buyers of grass residue, could alter the relative price structure so as to favor residue. Either potential sellers or potential buyers could be subsidized by (1) direct payments, (2) indirect payments, or (3) some combination of both.

Direct subsidy payments would be intended to make the *net* market price of grass residue economically equivalent or competitive with market prices of alternative raw materials (inputs). If grass seed producers sold their residue at a price which is competitive with the price of alternative inputs (but is lower than their supply price of residue), a direct payment to them (farmers) could be made to offset costs of residue densification, collection, storage, transportation, etc. The level of subsidy could be as great as the difference between the producers' supply price of residue and the market price of a substitute input. Or, users of straw residue could buy it on a cost basis and be reimbursed by the subsidy for the difference between cost of residue and market price of alternative raw materials. The assumption here, of course, is that buyers of residue would be indifferent between use of residue and alternative raw materials except for price (cost) differentials.

Indirect subsidy payments involve monetary concessions offered to attract new paper mills or livestock feedlots to the state as potential demanders of grass residue. Such payments may include direct cash outlays to partially offset plant establishment costs for potential paper mills which would use grass residue in their pulping process, provision of investment credit at an interest rate lower than the market rate of interest, corporate income or property tax exemptions, etc. Indirect subsidies to potential suppliers of residue could take the form of property tax exemptions, subsidies on the purchase of plant and equipment employed to collect, densify, and store residue, etc.

The subsidy payments need to be defined in accordance with (1) the interaction of demand and supply conditions in the residue market, (2) the demand conditions for the intermediate or final product, say pulp, paper, and fiberboard, or dairy products and red meats in the case of the livestock industry, and (3) the supply conditions of substitutes, e.g. woodchips, wood residuals, and fiber feeds. Since the residue could be utilized in at least two distinct industries, viz. livestock feed and pulp and paper making, the knowledge of these relationships becomes even more important. A priori, one would expect the elasticity of demand for residue in these two industries to be different. If so, the amount of subsidy required to make a given quantity of residue economically attractive to the livestock feed industry would be different than for the pulp industry. Subsidy levels would need to be determined by a simultaneous investigation of the responsiveness of demand in both markets. Economic theory suggests that the more elastic the demand for a finished product, the more elastic the demand for a factor of production, ceteris paribus [4]. Furthermore, the elasticity of demand for residue is directly related to the elasticity of supply of substitute raw materials. Therefore, other things equal, the more elastic the demands for intermediate or final products and/or the supply of substitute raw materials, the lower the amount of subsidy required to utilize a given quantity of residue.

Let us illustrate graphically the significance of a direct subsidy paid to the grass seed producers in facilitating the utilization of residue.[3] Assume that (1) grass residue could be used only in the pulp industry, and (2) residue and woodchips are perfect substitutes in the production of pulp.[4]

Now, consider Figure A, where D_a refers to aggregate demand for woodchips and/or residue. If the supply of woodchips and residue are represented by S_{wc} and S_r, respectively, the pulp industry is utilizing Q_{wc} tons of woodchips at equilibrium price P. At this price, no grass residue is utilized. A subsidy equal to kk′ paid to producers of grass residue as partial or full compensation for their costs of residue collection, densification, etc., would shift their marginal cost curves downward resulting in a market supply of residue of S_r'. This would shift the aggregate supply of woodchips and residue from S_a to S_a'. At the new short-run equilibrium price P′ (<P), Q_r' tons of residue would be utilized and the quantity of woodchips would decline from Q_{wc} to Q_{wc}'.[5] The total quantity of raw material utilized would increase to $Q' (= Q_{wc}' + Q_r')$.

Specification of Demand and Supply Relationships

This section specifies market demand and supply relationships for residue in both the dairy feed and pulp industries.

Demand for Residue as a Fiber Source in Dairy Feed. In preliminary feeding trials, grass residue has been combined with other feed components to provide a fattening ration for livestock. However, relatively high cellulose and lignin contents of grass straw indicate that it may be a more appropriate source of fiber for rumen stimulation and wintering rations for dairy cattle. The Japanese dairy industry has shown considerable interest in utilizing straw as a fiber source in lactation rations.

In specifying the demand for residue as a source of fiber in dairy feed, it is hypothesized that the quantity of grass residue demanded (1) varies inversely with a change in the price of residue, and (2) directly with the price of alternative fiber sources in livestock feed, and the number of dairy cattle in Japan.[6]

These relationships are stated formally as:

$$D_\ell = F(P_r, P_f, Z_j)$$

where:

D_ℓ = quantity of residue demanded as a fiber source for dairy feed,
P_r = price of residue,
P_f = price of alternative fiber sources, and
Z_j = number of dairy cattle in Japan.

Demand for Residue in the Pulp Industry. Research studies have shown that paper produced from residue, using either kraft or soda pulping processes, has excellent properties for the production of corrugating medium [5]. Laboratory results indicate that yield of pulp from straw residue is almost the same as from woodchips and wood residuals.

In specifying the demand for residue in pulp and paper making, it is hypothesized that the quantity of grass residue demanded varies inversely with the price of residue and directly with the price of woodchips, the price of pulp, and the quantity of corrugating medium demanded.[7] These relationships are stated formally as:

$$D_p = G(P_r, P_{wc}, P_p, Q_{cm})$$

[3] In illustrating the role of subsidies in promoting residue utilization, this paper focuses only upon subsidies paid to producers of grass residue. A parallel treatment of the impact of subsidies to buyers of residue can be accomplished in a similar fashion with the difference being one of analytics only. Direct payments to buyers on a cost basis, upon presentation of a receipt of residue purchase, could result in a shift in demand in favor of grass residue. Similarly, various kinds of indirect payments to those paper mills which would use straw (residue) in their pulping process could serve as demand shifters. This paper, however, is neutral regarding the use of one type of subsidy over the other, although there is some feeling among economists that consumer (buyer) subsidies are relatively less effective. A decision as to whether to subsidize buyers *or* sellers of grass residue, among other things, depends upon the income redistributive considerations and administrative costs of subsidy actions, and is not within the scope of this study.

[4] This assumption is made for analytical convenience only. It is readily admitted that residue and woodchips are not perfect substitutes in terms of fiber characteristics which affect the nature of the chemical process used in pulping.

[5] In the long-run, however, subsidization of grass residue will initiate several market adjustments which are discussed later in this paper.

[6] The number of dairy cattle in Japan which, in turn, may be a function of changes in demand for dairy products, population, tastes and preferences, etc., are assumed to be exogenous to the model. Evaluation of potential demand for residue as a fiber source in dairy rations indicates that the Japanese market may become an important outlet in the future [16].

[7] The model assumes that price of pulp and quantity of corrugating medium demanded are given exogenously. Guthrie [10] has indicated that structure of the pulp and paper industry is such that pulp prices are generally determined by price leadership. He has also pointed out that determinants of demand for paperboard (corrugating medium) are very difficult to conceptualize because of numerous alternative uses for paperboard. The quantity of paperboard demanded is influenced by diverse business firm demands for packaging materials which reflect demand for final products of these firms, of substitute containers in wooden, metal, or glass forms, and the general level of economic activity [10, p. 65].

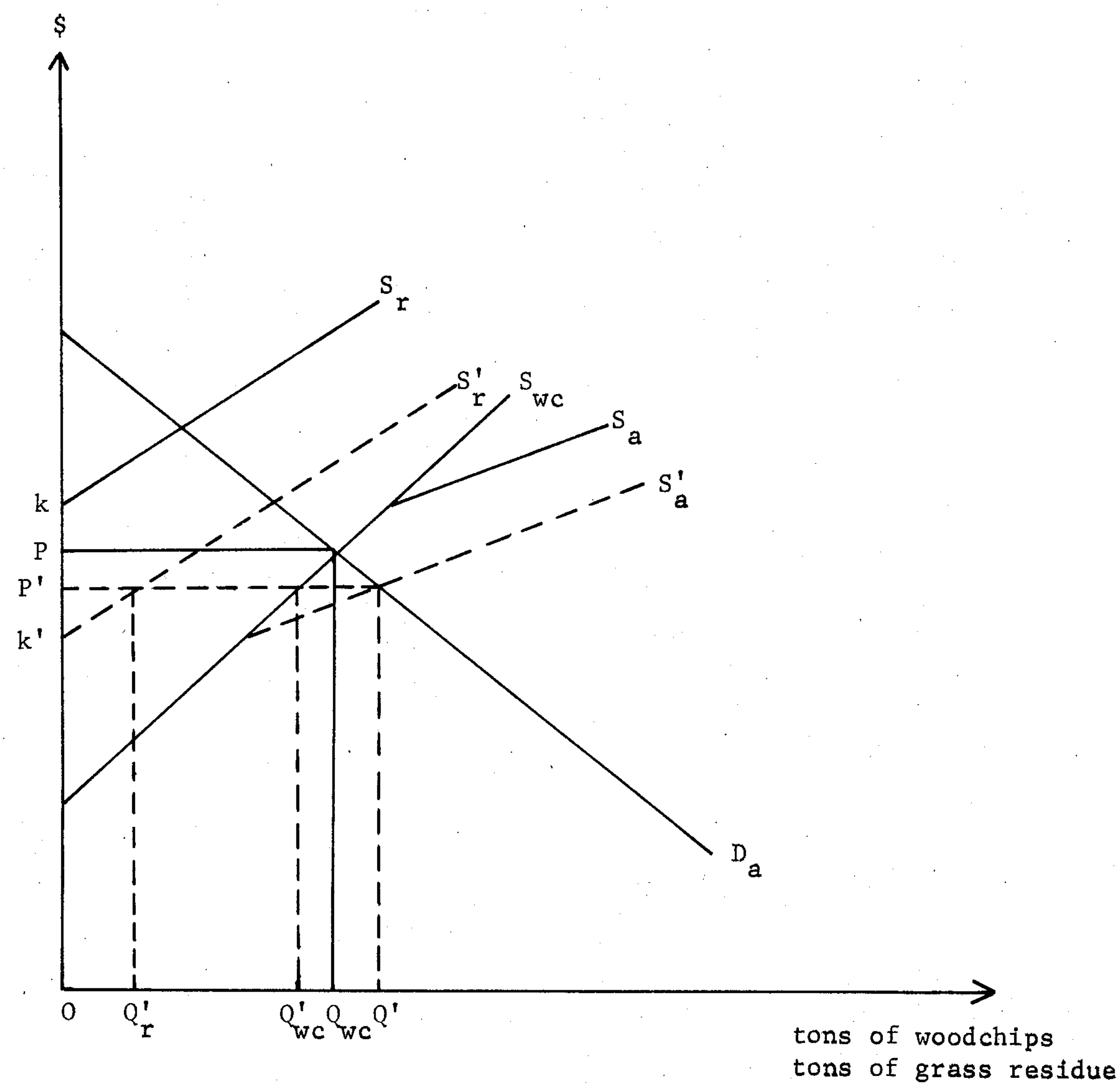

Figure A. DIRECT SUBSIDY PAID TO GRASS SEED PRODUCERS AND ITS IMPACT ON RESIDUE UTILIZATION

where:

D_p = quantity of residue demanded for pulp making,
P_r = price of residue,
P_{wc} = price of woodchips,
P_p = price of pulp, and
Q_{cm} = quantity demanded of corrugating medium.

Supply Relationships. Grass residue, a by-product of the Oregon grass seed industry, has zero market value at present. Removal of residue from the fields, and its conversion to a marketable product require collection, densification, treatment with binding agents in some cases, transportation, and storage. It is assumed that the residue in collected and densified form is a different product than residue left in the field, and that the former has a positive price.

It is postulated that the quantity of densified residue supplied depends directly upon the price of residue and the quantity of grass seed produced. The quantity of grass seed produced is endogenous to the model, and is hypothesized to be a function of time trend, lagged price of grass seed, and lagged quantity of grass seed produced.[8] The aggregate supply curve of grass seed is expected to shift upward and to the left in response to the increased costs of grass seed

[8] For a detailed specification of grass seed supply-response functions, see Brar [5]. A basic hypothesis underlying the specification is that grass seed producers, in response to changed market conditions, do not adjust their production perfectly in one time period; rather, they make a gradual adjustment to the planned long-run equilibrium level of production.

production as more costly methods are required after 1975 to substitute for open field burning. To account for this expected upward shift in costs, a dummy variable is included in the specification.[9]

The hypothesized supply relationships are formally stated as:

(1) $S_r(t) = H[P_r(t), Q_g(t)]$

and

(2) $Q_g(t) = Q[t, P_g(t-1), Q_g(t-1), D]$

Substituting (2) for $Q_g(t)$ in (1), we obtain

(3) $S_r(t) = H[P_r(t), t, P_g(t\text{-}1), Q_g(t\text{-}1), D]$

where:

$S_r(t)$ = estimated quantity of densified residue produced in time t,

$P_r(t)$ = price of residue in time t,

t = time trend,

$P_g(t-1)$ = lagged price of grass seed,

$Q_g(t-1)$ = lagged quantity produced of grass seed, and

D = dummy variable equal to 1 if the year of production is after the ban on open field burning, and zero otherwise.

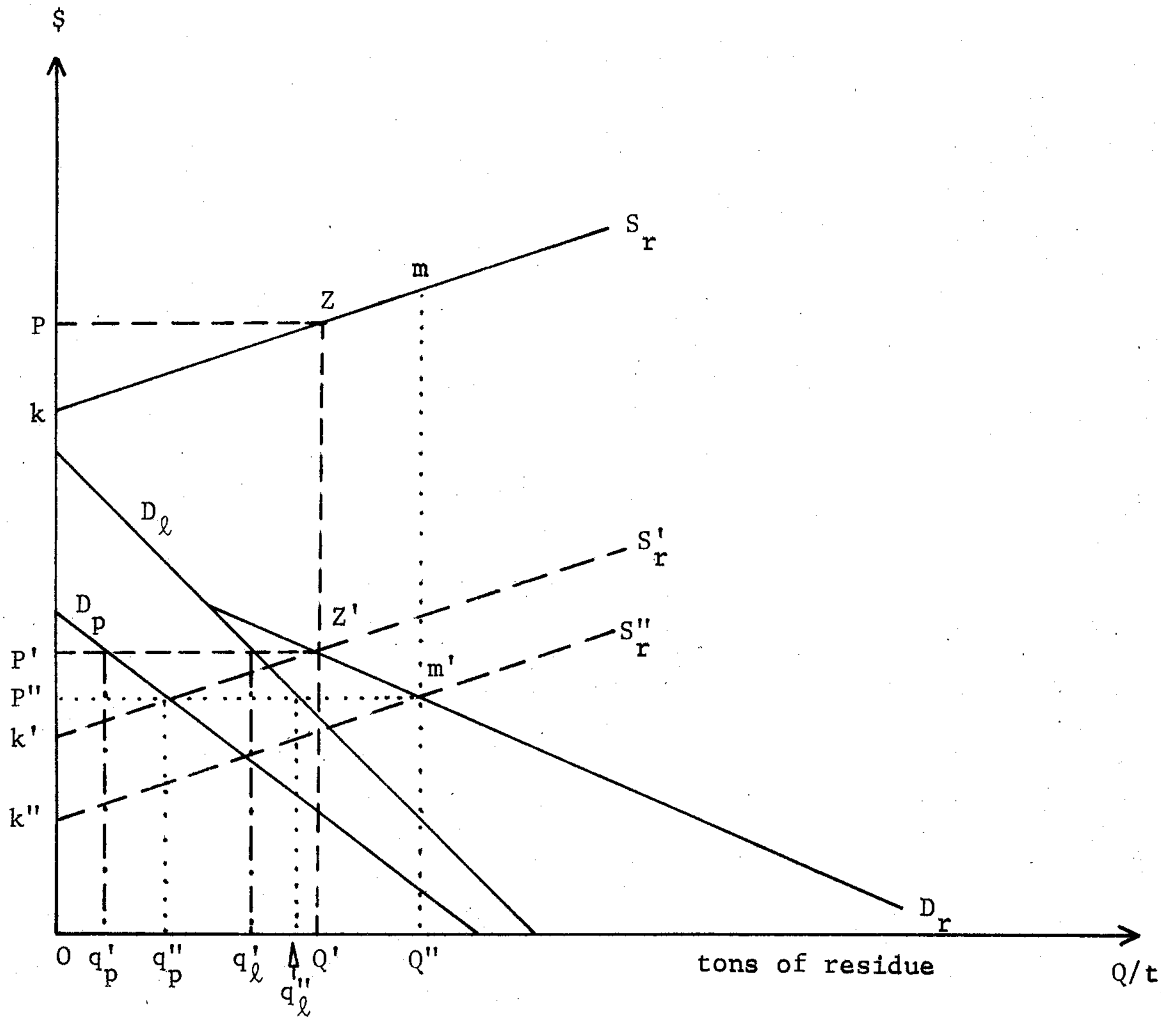

Figure B. IMPACT OF SELECTED SUBSIDY LEVELS ON RESIDUE UTILIZATION

[9] This is not to argue that, following the ban on open field burning, costs of grass seed production would increase for every farmer. Such a ban would be expected to induce internal resource use adjustment in the industry. Some of the marginal farmers may be forced to leave the industry, and as a consequence, those farmers remaining might expand their operations and benefit from economies of size. Thus, the cost of grass seed production may not increase for some farmers after adjustment.

Subsidies and Their Impact

This section discusses the effects of selected subsidy levels on residue utilization, economic well-being of buyers and producers of residue, and the market for raw materials entering animal feed and pulp markets. The subsidy, an autonomous change in spending at the regional or state level, would have multiple effects as well [15]. Additional payrolls generated by employment in the newly established paper mills and/or trucking industry may increase consumption and investment at the local level. A brief reference to this likely impact of a subsidy is made in the section of benefit-cost analysis.

Impact on Residue Utilization. Assume that in Figure B, D_ℓ and D_p refer to demands for residue as a source of fiber in dairy feed and as a raw material in pulp making, respectively, and D_r equals $D_\ell + D_p$. The supply curve of residue, S_r, is drawn assuming that the minimum supply price is so high that effective demand for residue is non-existent. To supply Q′ tons of residue, the suppliers would accept the price 0P, whereas buyers are willing to offer 0P′ (<0P) for the same quantity.

One way to bring about a short-run market equilibrium would be to provide a subsidy equal to kk′ to suppliers of residue. This subsidy will compensate them partially or fully for the cost of residue collection, densification, storage, etc., and would shift the marginal cost curve of individual producers downward resulting in a market supply of S_r'. The new short-run equilibrium price will be 0P′. At this price, Q′ tons of residue would be utilized with q_ℓ' tons going as animal feed and q_p' tons for pulp and paper making. However, if the quantity of residue supplied equals Q″ tons (>Q′), a subsidy equal to kk″ (>kk′) would be required to permit Q″ tons to be commercially utilized.

In the long-run, supply and demand conditions in residue and related markets may change in response to residue subsidization or to several other economic factors. This, in turn, would influence the subsidy and residue utilization levels. A subsidy to compensate producers can be expected to induce entry of new producers, thereby increasing the supply in the long-run, and possibly lowering the price. Since residue is a by-product of the grass seed industry, new producers probably will not enter the residue market unless the subsidy increases profitablilty of grass seed production directly. This appears unlikely.

Impact on Well-Being of Buyers and Sellers. Consider Figure C where, for expositional convenience, D_r represents the aggregate demand for residue and curve S_r refers to long-run supply situation. In order that 0Q′ of residue are utilized, a subsidy equal to kk′ per ton is required. The total monetary cost of this subsidy to society would be the area PLNP′. The gain to consumers would be the area indicated by MP′N and the gain to producers would be the area indicated by PLK = P′k′N, respectively.[10] The "net cost of the subsidy to society is given by kMNL(= PLNP′ – MP′N – PLk).

It can be observed that gains to buyers and producers of residue will depend upon elasticity of demand and supply curves. If demand is perfectly elastic at 0P′, buyers will experience no gain. Similarly, if supply is perfectly elastic, there will be no producers' surplus. Excluding these two extreme cases, any gains to the buyers and producers of residue resulting from a social subsidy will be influenced by elasticities of the demand and supply curves. The smaller the gains to consumers and/or producers, the larger becomes the net monetary cost of a subsidy paid by society.

Impact on Utilization of Substitute Raw Materials. The previous sections indicated the importance of economic conditions in the markets for substitute raw materials in determining the subsidy levels. By the same token, changes in the residue market brought about by the use of subsidies could, in turn, influence the markets for substitute raw materials. Since demand for an input, among other things, depends upon the price of substitute inputs, a subsidy on grass residue could generate leftward shifts in demand for substitute raw materials such as woodchips and other fiber sources in animal feed. Assuming less than perfectly elastic supply curves of such raw materials, these shifts would result in lower price and quantity utilized for woodchips and other fiber sources.

For illustration, refer to Figure D. Along the demand curve for wood residuals (D_{wc}), the price of the final product (P_f), say paper, fiberboard, or corrugating medium and a hypothetical price of residue (P_r) are assumed to be constant. Now assume that subsidization of grass residue market generates a price of residue $P_r' < P_r$. This change in price leads to a shift in the demand curve for wood residuals from

[10] In indicating gain to buyers, it is assumed that the area under the derived demand curve is approximately equal to "true" consumers' surplus. This assumption is not too unreasonable. Schmalensee has pointed out that, under certain conditions, the area under a derived demand curve can be exactly equal to "true" consumers' surplus [18]. Specification of gains in producers' surplus is based on a long-run supply curve. Although literature, or the use of a relevant supply curve in estimating the changes in producers' surplus, is controversial, Mishan suggests that, for a public policy decision, the area above a long-run competitive supply curve represent producers' surplus [14].

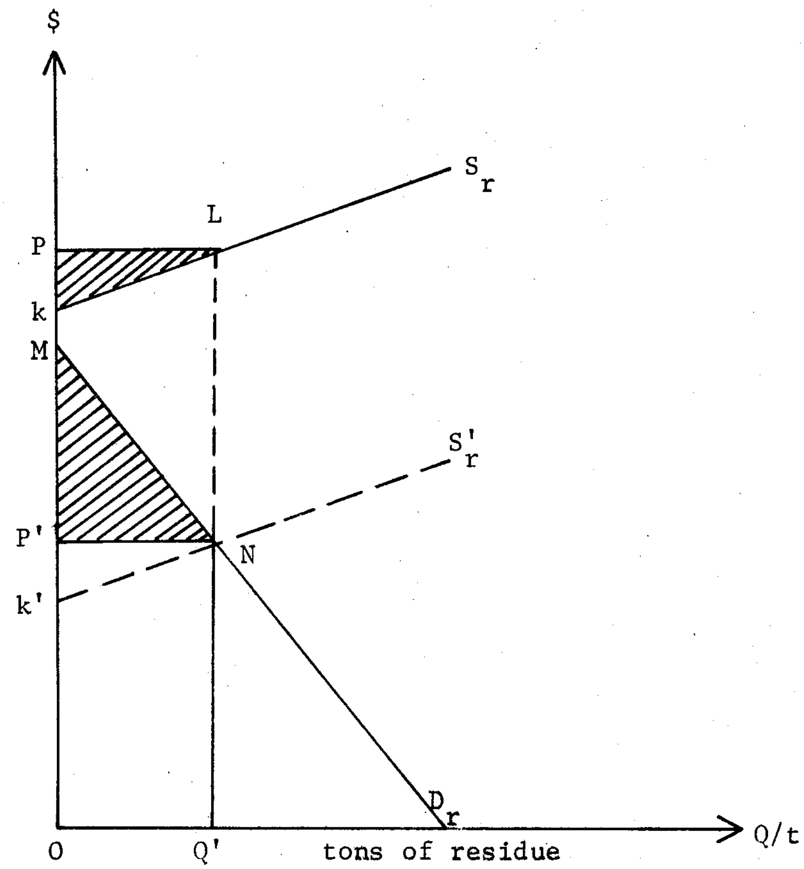

Figure C. ECONOMIC WELL-BEING OF BUYERS AND SELLERS OF RESIDUE AND MONETARY COST OF A SUBSIDY

D_{wc} to D'_{wc}, lowering the price of wood residuals from P'_{wc} to P_{wc} and quantity utilized from Q_{wc} to Q'_{wc}.[11]

In the long-run, any decline in price of woodchips (residuals) from P_{wc} to P'_{wc} may result in (1) a change in the price of the finished product, (2) a leftward shift in the demand for grass residue, and (3) supply adjustments in woodchips and wood residual markets.[12]

Some Difficulties

The preceding section focused mainly on economic aspects of a subsidy from a short-run viewpoint. Only brief reference was made to the long-run impact of a subsidy. Departure from short-run considerations introduces complexities to the decision process since, from an intertemporal standpoint, no single or fixed level of subsidy will be optimal.

In the long-run, developments of new markets for grass residue, introduction of new substitute methods for open field burning, changes in demand for residue in animal feed, and pulp and paper making, new standards on environmental quality, and many other social and economic changes could influence subsidy requirements. Incorporation of these and many other variables would make it difficult to present the analysis in a graphical form.

The long-run stability of residue supply also will be of considerable importance in any policy decision. If potential paper mills perceive uncertainty in future residue supplies, the subsidy may not prove to be very effective. This may be particularly true because woodchip supply is relatively more stable over time, and plant establishment costs in the pulp and paper industry are very high. Since grass residue is a

[11] The shift in D_{wc} and subsequent decline in price to P'_{wc} could result in losses in consumers' and producers' surpluses in the wood residuals market. However, the wood residuals market is relatively large and the possible shift in D_{wc} may not be significant. Thus, the model assumes that in estimating the net costs of a social subsidy, such losses, if any, are not significant from society's viewpoint.

[12] In a similar fashion, impacts from a subsidy on the market for alternative fiber sources in livestock feed also can be studied.

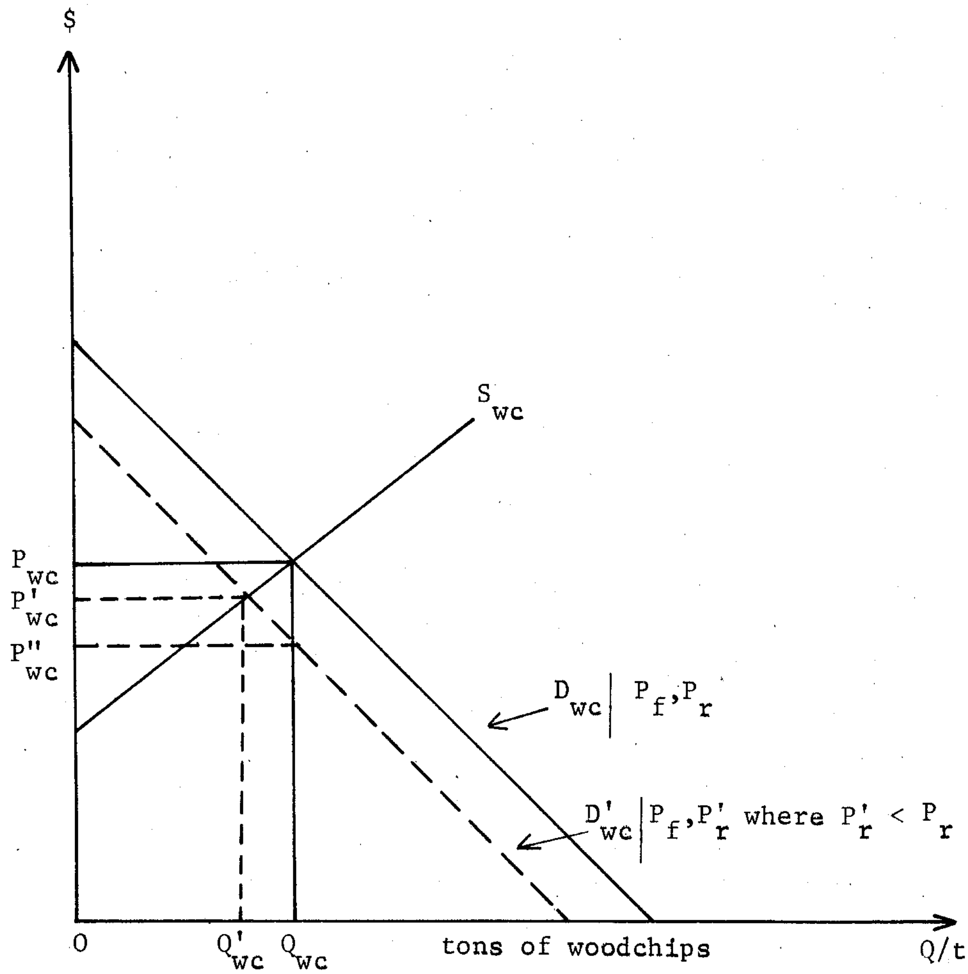

Figure D. IMPACT OF A SUBSIDY ON UTILIZATION OF WOODCHIPS

by-product of the grass seed industry, the long-run stability of its supply will depend primarily upon the survival of the parent industry. This, among other things, would be determined by changes in the nature of interregional and international competition in the seed industry, relative profitability of farm enterprises over time, competition with synthetic industries such as artificial turf, and development of market access control by use of proprietary varieties, marketing orders, etc.

Benefit-Cost Analysis

Economic criteria, as specified in the previous sections, do not imply that a subsidy level so defined will be desirable from a social viewpoint as well. To determine social desirability of a subsidy, benefit-cost analysis, as commonly employed in public investment evaluation, can provide a meaningful frame of reference [11, 13]. An implication of this would be that delineation of total benefits and costs of a subsidy to society be undertaken.

Since subsidization of residue utilization implies no open field burning, benefits that will accrue from improvements in the environment such as improved visibility, better health conditions of the residents of the state, increased tourist and resident recreational activities, etc., should be evaluated along with the gains in consumers' and producers' surpluses in the grass residue market and the increase in payroll incomes of the community generated by additional employment opportunities. In the benefit-cost analysis, specific attention should be given to (1) the subjectivity involved in estimating the social benefits, (2) multiplier effects of a polyperiod autonomous change in spending at the state level, and (3) distribution of social benefits and costs.

SUMMARY AND CONCLUSIONS

A policy decision to subsidize the utilization of grass residue involves both economic and social criteria. Economic criteria suggests that magnitude of subsidy payments must take market forces into account, since such payments are intended to alter relative prices so as to favor straw residue. This paper has sought to identify and describe the significance of demand and supply characteristics of residue, demand characteristics for final products, and supply characteristics of alternative raw materials as important market forces from a static point of view. From an intertemporal standpoint, relative riskiness in supply of grass straw, along with possible changes in market conditions, also were treated.

A subsidy based on economic criteria does not imply that it also will be desirable from a society's viewpoint. As in the case of other social investments, it must be asked whether a subsidy to promote utilization of residue in some broad sense can improve social well-being. To answer this question, benefit-cost analysis can provide an appropriate analytical framework. While this paper specifically used grass residue for exemplary purposes, the framework can be helpful for other by-products where environmental issues are pressing for more acceptable disposal or utilization alternatives.

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