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**Effects of Market Power on the Size and Distribution of Subsidy Benefits:
The Case of Ethanol Promotion**

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Tina L. Saitone

*Agricultural and Resource Economics Department
University of California, Davis
saitone@primal.ucdavis.edu*

Richard J. Sexton

*Agricultural and Resource Economics Department
University of California, Davis
rich@primal.ucdavis.edu*

and

Steven E. Sexton

*Agricultural and Resource Economics Department
University of California, Berkeley
ssexton@are.berkeley.edu*

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Effects of Market Power on the Size and Distribution of Subsidy Benefits: The Case of Ethanol Promotion

Biofuels have generated a great deal of interest among developed and developing countries as a way to simultaneously reduce imports of petroleum and reduce air pollution caused by the combustion of fossil fuels. Heightened concerns about global climate change, expanding demand and increasing oil prices, and instability in oil-exporting countries have led to considerable efforts in the U.S., Europe, India, China, and Australia to promote biofuels as an alternative to fossil fuels. In the U.S. attention has focused principally on ethanol derived from corn feedstocks.¹ President George W. Bush proposed in his 2005 State of the Union address that ethanol could break the U.S. “addiction” to oil.

Since its inception, ethanol has been unable to compete with petroleum. Under current production methods, ethanol costs \$0.50 more per gallon to produce than petroleum. Therefore, governments have resorted to extensive promotion programs to spur ethanol production. In the U.S., the primary instrument of the federal government is a \$0.51 tax credit per gallon of ethanol produced. The total cost of ethanol subsidies in the U.S., including state and federal programs affecting every level of the supply chain, including support for output, factors of production, intermediate goods, and consumption is estimated to be \$5.1 billion in 2006, rising to as much as \$8.6 billion in the near term (Koplow, 2006). The ethanol subsidy is intended to both promote the diffusion of ethanol and to support farmers, who are believed to gain considerably through widespread adoption of ethanol produced from corn. The farm lobby has supported ethanol subsidies as a top priority for its members because they are seen as a more politically feasible instrument than price supports, given the dominance of environmental considerations in domestic policy. Though ethanol is believed to increase farm income, it is recognized there will be

¹ Brazil has generated considerable ethanol from sugar cane and the EU and India produce relatively large quantities of biodiesel from soy and palm oil.

winners and losers in agriculture. For instance, livestock producers are expected to suffer because of high feed costs whereas corn producers will benefit. Gardner (2003) compares the gains to farmers from such demand-inducing subsidies and regulation to traditional commodity promotion regimes and concludes the strategy of the National Corn Growers and other industry groups may be optimal given that they can rely on the lobbying resources of ethanol producers.

Most of the literature analyzing agricultural subsidies assumes perfectly competitive markets, with Gardner (1987) representing a prototype treatment. Gardner (2003) in his evaluation of ethanol subsidies also assumes perfectly competitive markets.² However, evidence of market power among seed producers like Monsanto and DuPont and among grain processors like Archer Daniels Midland and Cargill suggests that the competitive paradigm may not be appropriate, raising the question of whether analyses that rely upon it are able to capture the true size and distribution of benefits from ethanol subsidies and regulation.

This paper develops a prototype model for determining the production and price impacts and distribution of benefits from the ethanol subsidy when market power may be exercised upstream from the farm in the seed sector and downstream in the corn-processing sector. It is not the goal of this paper to estimate the extent of market power in the corn sector, although we do offer evidence in support of the proposition that market power may be important. Rather, our goal is to illustrate how upstream and downstream market power influences the market effects of the ethanol subsidy and who benefits from it.

Our model draws upon the methods of Alston, Sexton, and Zhang (ASZ,1997) and Gardner (2003). ASZ utilized a conjectural variations model of buyer and seller market power exercised by downstream processing firms to determine the effect of imperfect competition on

²The policy literature that does consider the effects of imperfect competition, generally assumes pure monopoly or monopsony, which may no better represent industry structure than a model of perfect competition.

research benefits. Our model extends the literature by permitting the exercise of seller power upstream from the farm sector and buyer power downstream and by providing a specific application to ethanol subsidies. Substantial market concentration and subsidies observed in the U.S. for ethanol production exist in other countries as well, so we might anticipate that the results from this paper also apply broadly to other countries.

This paper proceeds with a brief background on ethanol and discussion of the industry structure. The model of imperfect competition is then developed. The model is then parameterized to approximate conditions for ethanol production in the U.S. and the impact of the subsidy is analyzed within a simulation framework for alternative levels of market power. A discussion of the results and possible extensions are offered in conclusion.

Overview of the Ethanol Industry

Since the oil crisis of the 1970s, ethanol has been touted as an alternative to fossil fuels. Today, the technology is mature and demand for ethanol is growing. Ethanol is seen as a fuel extender, an oxygenate replacement for the toxic MTBE, and a renewable fuel source that can replace gasoline and reduce emissions of greenhouse gases. Federal and state policies are also driving demand. The Federal Government has banned MTBE in areas that fail to meet federal air quality standards, and many states have outlawed it entirely. In addition, the Energy Policy Act of 2005 (EPACT, 2005) establishes a Renewable Fuels Standard that requires 7.5 billion gallons of renewable fuel be used by 2012. EPACT 2005 also reauthorizes a \$0.51 tax credit per gallon of ethanol production.

The net energy benefits (NEB) of corn ethanol are small. When analysis incorporates the animal feed byproduct of ethanol production, the NEB is between 1.25 and 1.34 units of fuel energy per unit of fossil fuel input (Hill et al., 2006 and Shapouri et al., 2002). Farrel et al.

(2006) estimate that ethanol reduces greenhouse gas emissions by 13 percent after accounting for emissions during production. Under assumptions of continued upward trends in oil prices and downward trends in ethanol production costs, 25 percent renewable standards could reduce U.S. energy expenditures by 2025 (Bernstein et al., 2006).

Ethanol production proceeds by removing sugar from corn and other starchy crops with enzymes and then fermenting the sugar to alcohol with yeasts. The process yields 2.8 gallons of ethanol per bushel of corn and 17 pounds of distiller dried grain solubles, a byproduct added to livestock and poultry feed. An estimated five billion gallons of ethanol were produced in 2006 from 1.8 billion bushels of corn—more than 17 percent of the domestic harvest. This level of production is expected to cost the federal government in excess of \$2.5 billion for the output subsidy alone.

Current production capacity in the U.S. totals five billion gallons per year with another two billion gallons of capacity under construction. Archer Daniels Midland (ADM) owns in excess of 1 billion gallons of capacity and Verasun Energy Corporation, the next largest producer, has less than one-fourth the capacity of ADM. ADM has announced plans to dominate the biofuels industry, with CEO Patricia Woertz describing the company as being “in a category of one” (New York Times, 2006). Hodge (2002) reported that ADM had a 41 percent U.S. market share for ethanol.

If we broaden the product market category to include all wet corn processing, the four leading firms, ADM, Cargill, Staley and CPC International, held a combined 74% market share in 1997 (MacDonald and Denbaly, No Date). Although markets for processed corn products would tend to be national or international in geographic scope, the farm market for procurement of corn is localized due to high shipping costs, meaning that concentration in procurement markets is higher than the national figures indicate.

These levels of concentration, especially in light of the relevant geographic markets for procurement, are consistent with the possible exercise of unilateral market power by processors purchasing corn from farmers, for example, as exemplified in a Cournot-Nash equilibrium. In addition, market power may be attained through collusive behavior. It is significant, in this latter regard, that ADM was convicted recently for colluding to fix prices to buyers of corn products (Connor, 2001).³ Thus, high concentration in the downstream industry, the prospect for unilateral market power, and the industry's track record of collusive behavior give reasons for concern that corn-products manufacturers may exercise market power in procuring the raw product from farmers.⁴

Upstream, four firms, DuPont, Monsanto, Novartis and Dow, account for 69 percent of corn seed sales in the U.S. (MacDonald and Denbaly, No Date). Sixty percent of the 2006 corn crop was planted using genetically modified seed. Agricultural biotechnology has yielded crops that are resistant to the chemical herbicide Round-Up and that include the naturally occurring pesticide *bacillus thuringiensis*. These genetic advances have increased yield and reduced production costs, particularly pesticide costs.

The percentage of corn planted using GM seed is expected to continue increasing. Consistent with the literature on research and development, intellectual property rights and innovation, growing reliance on genetically modified seed can be expected to increase corn seed industry concentration (Phillips 1956, 1966; Mansfield 1962, 1983; Winter, 1984; Swann and Gill, 1993; Barton, 1998). R&D generally allows large firms to extend their profit advantage

³ Although Cargill was not implicated directly in these price-fixing cases, Connor (2001) argues that considerable evidence suggests Cargill's involvement with ADM in arrangements to fix price.

⁴ Although the extent of concentration in the corn processing sector is also consistent with the exercise of oligopoly power in the sale of corn products, we assume perfect competition in ethanol sales to simplify the analysis, and focus on the implications of oligopsony power by the processors in procurement of corn from farmers. Powerful downstream buyers likely could countervail attempts by corn processors to exercise oligopoly power. This focus is also consistent with the recent report by the U.S. Federal Trade Commission (2006) which concluded that ethanol sales were likely to be conducted on a competitive basis.

over smaller firms (Rosen, 1991). Further, the absorptive capacity of incumbent firms predicts their persistence (Cohen and Levinthal, 1989, 1990). Because innovating firms are conferred limited monopoly status by intellectual property rights, they will attempt to capture the benefits of their innovations through monopoly pricing. In the context of innovation by suppliers of agricultural inputs, benefits that are commonly believed to accrue to consumers and agricultural producers, may be largely captured by innovating firms (e.g., Moschini and Lapan, 1997).

The Model

To enable the model to be as general as possible in terms of its depiction of alternative levels of competition, we seek to simplify other aspects of the model. We assume that corn seed is used in fixed proportion in corn production, and without further loss of generality, through choice of measurement units, set the Leontief coefficient to 1.0 for converting corn seed to corn production. We assume homogeneous farmers, and specify the representative farmer's profit maximization problem as:

$$\underset{\{q\}}{Max} \quad \pi = pq - Pq - c(q), \quad (1)$$

where p is the farm price for corn, P is the price for seed, q is the individual farmer's corn output and seed input, and $c(q)$ represents costs for other inputs into corn production that do not necessarily enter production in fixed proportion. We assume $c'(q) > 0$, and $c''(q) > 0$. The first order condition is

$$(p - P) = c'(q). \quad (2)$$

To obtain analytical solutions and provide a convenient platform for simulation, let $c(q) = \frac{1}{2}\beta q^2$. Then $c'(q) = \beta q$ and $p = P + \beta q$ defines the individual farmer supply

relationship. Solving for q , we obtain $q = \frac{p-P}{\beta}$, which defines the direct supply relationship for the representative farmer. Aggregating over n homogeneous farmers, the industry supply in the corn market is

$$Q = \sum_{i=1}^n q_i = nq = n \frac{p-P}{\beta}. \quad (3)$$

Production is increasing in output price and number of farmers and decreasing in seed price and the marginal costs due to other inputs. Given fixed proportions between corn seed and corn production, (3) also represents the input demand for seed. We assume a constant marginal cost, w , of seed production, which represents the seed industry's supply curve in the case of perfect competition.

The corn price is exogenous to the individual producer but is endogenous at the market level. In the absence of the ethanol subsidy let the aggregate farm-level demand for corn for all uses be represented by the linear function:

$$Q = a - bp. \quad (4)$$

The analysis is simplified, without loss of generality, by utilizing the available normalizations. Thus, we set the number of producers to $n=1.0$, and normalize the competitive equilibrium quantity to be 1.0 and the competitive equilibrium price of corn to be 1.0. To accomplish these normalizations, we solve simultaneously for the competitive equilibrium in both the seed and corn markets

$$a - bp = (p - P) / \beta$$

$$w = P = p - \beta Q$$

respectively.

Solve the seed market equilibrium condition for $Q^* = 1.0$ and then solve that condition for the relationship which must hold between w and β :

$$Q = \frac{p - w}{\beta} = \frac{1 - w}{\beta} = 1 \rightarrow \beta = 1 - w ,$$

The seed price under competitive equilibrium, has the interpretation as the cost share of the seed input under perfect competition, while β represents the combined share of other inputs under perfect competition.

We then solve the corn market competitive equilibrium condition for p and set $p = 1$ to solve for the relationship that must hold between the demand parameters:

$$p = \frac{a\beta + w}{1 + b\beta} = \frac{a(1 - w) + w}{1 + b(1 - w)} = 1 \rightarrow a = 1 + b.$$

Finally, we eliminate the unit-dependent demand slope parameter, b , with the unit-free demand elasticity, η , evaluated at the competitive equilibrium:

$$\eta = \left| \frac{\partial Q}{\partial p} \frac{p}{Q} \right| = b \frac{1}{1} = b.$$

Given these preliminaries, we can rewrite farm supply in the corn market as

$$Q = (p - P)/(1 - w), \tag{5}$$

and the farm demand relationship in the corn market as

$$Q = 1 + \eta(1 - p). \tag{6}$$

The supply relationship in the corn seed market is defined by the constant marginal cost function

$$MC = w = P, \tag{7}$$

and seed demand is given by (5) or, alternatively, in inverse form as

$$P = p - Q(1 - w). \tag{8}$$

To depict the possible exercise of oligopsony power in the raw corn market, we utilize the concept of a perceived marginal cost curve, $PMC(Q|P)$. At each quantity $PMC(Q|P)$ lies between $p = S(Q|P) = P + (1-w)Q$, the inverse industry supply curve, and $MC(Q|P) = P + 2(1-w)Q$, the marginal acquisition cost curve facing a monopsonist.

Following ASZ, we write $PMC(Q|P, \theta) = (1-\theta)S(Q|P) + \theta MC(Q|P)$, where $\theta \in [0,1]$ and represents the degree of buying power on the part of corn processors. The greater is θ , the greater is the purchasing power of the oligopsony buyers, with $\theta=1$ representing pure monopsony behavior, and $\theta=0$ denoting perfect competition.

Analogous to the PMC function used to depict downstream oligopsony power, we utilize the concept of a perceived marginal revenue (PMR) curve to depict oligopoly power of seed sellers. Given farmers' inverse demand function for seed, $P(Q|p, w) = p - Q(1-w)$, the marginal revenue function facing a monopoly seed seller is $MR(Q|p, w) = p - 2(1-w)Q$. Then we define PMR as a linear combination of P and MR, depending upon the degree of oligopoly power possessed by seed producers, $PMR(Q|p, w, \xi) = (1-\xi)P(Q|p, w) + \xi MR(Q|p, w)$. The parameter $\xi \in [0,1]$ indicates the degree of seller market power, with higher values of ξ denoting greater levels of selling power in the corn seed industry, with $\xi=1$ representing the case of pure monopoly behavior and $\xi=0$ depicting perfect competition.

Now consider the imposition of a per-unit production subsidy on ethanol production. The subsidy lowers the marginal cost of ethanol processing, effectively increasing the farm-level demand for corn used in ethanol production by the amount of the per-unit ethanol subsidy times the number of units of ethanol produced per unit of corn. Denote this corn-units-equivalent subsidy by τ . This subsidy shifts the aggregate farm-level demand for corn but in a way that

depends upon the relative importance of ethanol production as part of total corn demand.

Let $\tau^T < \tau$ denote the shift in total (T) corn demand caused by the ethanol subsidy. We subsequently derive τ^T based upon the parameterizations used in our simulation model. Inverse

farm-level demand for corn in the presence of the ethanol subsidy is thus: $p = \frac{\eta+1}{\eta} - \frac{Q}{\eta} + \tau^T$

We are interested in studying equilibrium in the corn and seed corn markets under various market structures: (i) perfect competition in both markets, (ii) oligopsony in corn procurement, and perfect competition in seed sales, (iii) perfect competition in corn procurement and oligopoly in seed sales, and (iv) oligopsony in corn procurement and oligopoly in seed sales. By solving the most general case (iv), we can obtain solutions to the other cases with the appropriate restrictions on θ and ξ as follows: Case (i) $\xi = \theta = 0$, case (ii) $\theta > 0, \xi = 0$, case (iii) $\theta = 0, \xi > 0$.

Equilibrium in case (iv) is determined by equality of $PMR(Q|p, \xi)$ and marginal cost in the seed market

$$w = (1 - \xi)(p - Q(1 - w)) + \xi(p - 2Q(1 - w)), \quad (9)$$

and equality of demand and $PMC(Q|P, w, \theta)$ in the corn market

$$(1 - \theta)(P + Q(1 - w)) + \theta(P + 2Q(1 - w)) = \frac{\eta+1}{\eta} - \frac{Q}{\eta} + \tau^T. \quad (10)$$

Equations (8), (9), and (10) represent a system of three equations that can be solved simultaneously to yield equilibrium values for the three endogenous variables, p, P, and Q:

$$Q^* = \frac{(w - \tau^T - 1)\eta - 1}{(w - 1)\eta(\xi + \theta + 1) - 1} \quad (11)$$

$$p^* = \frac{\eta+1}{\eta} - \frac{Q^*}{\eta} + \tau^T \quad (12)$$

$$\begin{aligned}
P^* &= \frac{\eta+1}{\eta} - \frac{Q^*}{\eta} - Q^*(1-w) + \tau^T \\
&= \frac{\eta+1}{\eta} - \frac{[Q^*(1+\eta(1-w))]}{\eta} + \tau^T
\end{aligned} \tag{13}$$

For $\xi, \theta \in (0,1)$ the comparative static results are as follows:

$$\frac{\partial Q}{\partial \xi} = \frac{\partial Q}{\partial \theta} < 0, \frac{\partial Q}{\partial w} > 0$$

$$\frac{\partial p}{\partial \xi} > 0, \frac{\partial p}{\partial \theta} < 0$$

$$\frac{\partial P}{\partial \xi} > 0, \frac{\partial P}{\partial \theta} \leq 0, \frac{\partial P}{\partial \eta} \leq 0, \frac{\partial P}{\partial w} > 0.$$

The comparative static results: $\frac{\partial Q}{\partial \eta}$, $\frac{\partial p}{\partial \eta}$, and $\frac{\partial p}{\partial w}$ cannot be signed without some assumption

about the degree of both upstream and downstream market power.

In this model, the impact of a given degree of corn processor oligopsony power and seed producer oligopoly power on output (and seed input) is identical, with each declining in the magnitude of market power exercised. Further, if we define $p - P$ as farmers' gross margin, the same result holds, namely $\partial(p - P)/\partial \xi = \partial(p - P)/\partial \theta < 0$. Oligopsony power reduces the farm price for corn and also the seed price, as long as $\xi > 0$, because lower farm prices for corn reduce the demand for seed, while oligopoly power in the seed market increases the seed price and, to a lesser degree, also the corn price, due to the shift upward in supply it creates.

Figures 1 and 2 illustrate the model for the cases (ii) and (iii) respectively. In both cases the market-power equilibrium is presented relative to the competitive equilibrium. The most general case of both oligopoly and oligopsony power, case (iv), is too complex for a convenient graphical exposition. In figure 1 the subscript S denotes oligopsony solutions, while subscript C denotes perfect competition. Superscripts 0 and 1, respectively, denote equilibria with no

subsidy and with the subsidy. The ethanol subsidy increases both the total production of corn and seed. The higher corn production also increases the farm price for corn, as farmers move along their supply curve, $S(Q|w)$. The seed price is unaffected due to the simplifying assumption of a flat seed supply curve under perfect competition. The same qualitative effects occur under oligopsony, but the effects are muted as the oligopsony buyers capture a portion of the subsidy benefit by restricting the amount of additional corn they procure in response to the subsidy relative to perfect competition: $Q_C^1 - Q_C^0 > Q_S^1 - Q_S^0$. Because output increases less under oligopsony power, the price increase and, hence, benefit received by corn farmers from the subsidy is less also under buyer oligopsony power: $p_C^1 - p_C^0 > p_S^1 - p_S^0$.

In figure 2, the subsidy causes higher corn production and output in panel (b), which causes the upstream seed demand curve to shift outward. Oligopoly seed producers (subscript O) capture a portion of the benefit of this demand shift by reducing the expansion of seed sales relative to perfect competition and charging a higher seed price. The increase in seed costs due to the subsidy increases the marginal cost of corn production, shifting the corn supply function back as indicated in panel (b). This supply shift in the corn market causes the expansion of corn production and, hence, the increase in corn price from the subsidy to be less under upstream oligopoly than under perfect competition: $Q_C^1 - Q_C^0 > Q_O^1 - Q_O^0$, and $p_C^1 - p_C^0 > p_O^1 - p_O^0$.

Simulation Analysis

Although comparative static results are important to indicate the direction of impacts from market power, the key questions pertain to the magnitude of these impacts and, in the case of the ethanol subsidy, how upstream and/or downstream market power affects production of corn for ethanol, the farm price of corn, and the distribution of benefits from the subsidy. We utilize a simulation framework parameterized to approximate conditions in the U.S. corn market to

illustrate the impacts of alternative levels of market power upstream and downstream from the farm.

To conduct the simulations, we need to specify ranges of values for the model's five parameters: the market power parameters, ξ and θ , the price elasticity of farm-level demand for corn, η , evaluated at the competitive equilibrium, the share of corn production costs due to corn seed under perfect competition, w , and the magnitude of the per-unit ethanol subsidy converted to an all-corn basis, τ^T . In all cases we set $\eta = 0.727$, based upon the estimate by Shonkwiler and Maddala (1985). The corn seed cost share is set at $w = 0.12$ (Foreman, 2001). Using (5), the elasticity of derived demand for seed at the competitive equilibrium is $|(\partial Q / \partial P)(P / Q)| = (1/(1-w))(0.12) = 0.136$.

A number of steps are required to convert the per-gallon ethanol subsidy to an all-corn basis. Begin with the current subsidy of \$0.51/gallon of ethanol produced and convert it to a corn input basis by multiplying by the 2.8 gallons/bushel basis. Next, we show in the appendix, that under some reasonable assumptions, conversion of the ethanol subsidy to an all-corn basis requires multiplying the subsidy on corn used for ethanol ($\$0.51 \times 2.8 = \1.43) by the share, s , of all corn production that is utilized for ethanol. We set $s = 0.2$, giving an all-corn subsidy of \$0.2856/bushel in nominal prices. Because the corn price is set to 1.0 at the perfectly competitive, no-subsidy equilibrium, the nominal ethanol subsidy must be converted to reflect this normalization. Of course, actual farm-gate corn prices reflect the true level of competition in the market, which is unknown, so the best we can do is take the average of actual prices for the most recent years and adjust them downward for the approximate contribution of the ethanol subsidy. Based upon USDA NASS statistics, the five-year average for the field corn price is \$2.40. A simple rule of thumb is to assume equal incidence of the subsidy between suppliers and demanders, meaning that the no-subsidy nominal price is $\$2.40 - (\$0.2856/2) = \$2.2572$.

Dividing the nominal, all-corn subsidy by this amount, $\$0.2856/2.2572 = \$0.1265 = \tau^T$, yields the appropriate value of the all-corn equivalent of the ethanol subsidy for the simulation model.

Simulation Results

The simulation results are summarized in figures 3-11. In all cases the horizontal axis of the figures indicates the degree of market power, either seed producer oligopoly power, corn processor oligopsony power, or both. Although we have no empirical basis to suspect levels of market power in the industry approaching pure monopoly or monopsony, for expository purposes we depict the entire range of possible market power values from zero to one. Similarly, we have no basis to believe that levels of market power exercised by seed manufacturers and corn processors would be identical. Presentation of equal levels of market power is purely for expository purposes.

The impacts of the ethanol subsidy on the farm price of corn, p , the gross farm margin, $p - P$, and production of corn (and seed), Q are reported in figures 3, 4, and 5, respectively. In each case, the impact is reported as a percent of the impact achieved under perfect competition. We see that oligopsony power exercised by the corn processors reduces the increase in the farm corn price relative to what would be achieved under perfect competition, although the effect for modest levels of oligopsony power is not dramatic. For example, for $\theta = 0.3$, the increase in farm price is 89.5 percent of the increase attained under perfect competition.

Oligopoly power exercised by seed producers has a substantial impact on the market because the demand for seed is very inelastic.⁵ Seed prices increase rapidly as a function of seed producers' oligopoly power, causing the farm supply of corn to shift back and the corn price to

⁵ The inelasticity of input demand for seed is a reflection of the well-known result that demand for an input is in general less elastic than the demand for the product the input produces, especially when the input has a low factor share and cannot substitute for other inputs (Bronfenbrenner, 1961), both of which are true in this model.

rise accordingly. The increase in the farm price due to the subsidy is 16 percent higher when seed producers exercise modest oligopoly power, $\xi = 0.3$, than when they sell seed competitively. However, in terms of the change in farmers' gross margin due to the subsidy, the negative impact of higher seed prices dominates the positive impact of higher corn prices, causing $\Delta(p - P)$ to decline as a function of upstream oligopoly power relative to the perfect competition benchmark. As figure 4 illustrates, equivalent degrees of oligopoly and oligopsony power have the same impact on the change in the gross farm margin in this model.

When equivalent degrees of oligopoly and oligopsony power are exercised simultaneously, the increase in farm price due to imposition of the subsidy is increasing, albeit slightly, as a function of the degree of market power exercised, but the increase in the gross farm margin from the subsidy is considerably less because the increase in the seed price dominates the increase in the corn price. For example, for $\xi = \theta = 0.3$ the change in $p - P$ is only about 80% of what is achieved under perfect competition.

Given that one of the goals of the ethanol subsidy is to expand ethanol production and reduce U.S. reliance on imports of fossil fuels, it is interesting to examine the impact of market power on the total amount of corn that is produced and available to produce ethanol and other corn products. Figure 5 reports these results. Market power reduces the expansion in corn production relative to what would be achieved under perfect competition, but the impact for moderate levels of oligopoly or oligopsony power is quite modest. For example for either ξ or θ equal to 0.3, the change in production is about 90 percent of what would be achieved under perfect competition. The impact on production is more severe, however, if market power is exercised at both stages. When $\xi = \theta = 0.3$, the production expansion is curtailed by about 20 percent relative to perfect competition.

These results on prices and outputs are consistent with the observation that the efficiency impacts of moderate levels of market power are quite minor (e.g., Sexton, 2000). Given that most of the concerns expressed about market power in the corn sector have focused on corn processor market power, it is noteworthy that in this model the impacts on output and the gross farm margin are identical for equal degrees of seed manufacturer oligopoly power and corn processor oligopoly power. Although this result of exact equality of impacts is not robust to alternative specifications of the model, the result that seed manufacturer oligopoly power has comparable effects to corn processor oligopsony power should be expected to hold generally.

Next we consider the impacts of market power on the distribution of benefits from the subsidy. Figures 6, 7, and 8 indicate the change in profits earned by farmers, corn processors, and seed producers as a function of the degree of seed producer oligopoly power, corn processor oligopsony power, and combined seed producer, processor market power, respectively. Figures 9, 10, and 11 provide the same information on a share-of-profit basis.

The distributional effects of market power are generally much larger. In the base simulation because corn demand is less elastic than corn supply, competitive processors capture about 60 percent of the subsidy benefits, while farmers capture the other 40 percent. Competitive seed producers capture none, due to the assumption that they supply with constant marginal cost. As figures 6 and 9 indicate, seed producers are able to capture significant benefits from the subsidy when they have oligopoly power. For example, when $\xi = 0.3$, seed manufacturers capture 19 percent of the subsidy benefits. When $\xi = 0.5$ (the equivalent of a symmetric Cournot duopoly), seed manufacturers in this model capture an identical benefit share to farmers—28 percent each. The benefits attained by both farmers and corn processors decline monotonically as a function of seed producers' oligopoly power.

When only processor oligopsony is exercised, the seed producers with constant marginal costs capture none of the subsidy benefits, but processors' share of the benefits rises monotonically as a function of their market power. The effect is somewhat more modest, however, than that due to seed producer oligopoly power, with the reason being that farm corn supply is much more elastic in this model (and likely in reality) than is seed demand. The distortion from market power is always multiplicative with the elasticity of the curve being exploited, so the relatively elastic farm supply limits the distorting impact of processor oligopsony power.

When market power is exercised both upstream and downstream from the farm, the absolute benefits and share of benefits from the subsidy attained by both farmers and processors decline as a function of the market power exercised. This somewhat surprising result for processors is explained again in terms of the larger distorting effect for seed producer oligopoly than for processor oligopsony due to the relative differences in corn supply and seed demand elasticities. Oligopsony power enables processors to reduce the price paid to farmers for corn, but input costs increase due to seed producer oligopoly power. This causes the farm supply curve to shift back, increasing the price of corn under any downstream market equilibrium. As figure 3 showed, this effect dominates with the parameterizations utilized in this model, and, hence, processors' benefits decline as a function of the degree of market power exercised. Although seed producers' subsidy benefit rises monotonically as a function of the degree of market power exercised in both sectors, the magnitude of their benefit is actually less in this case than when processors behave competitively because the price-and-output-depressing effect of oligopsony power reduces the farm demand for seed.

Finally, figure 12 depicts the total combined benefits earned by seed producers, farmers, and corn processors from the ethanol subsidy. The expectation, of course, is that the total

benefits decline as a function of the market power exercised because market power curtails the expansion of output relative to that attained under perfect competition, and some of the potential subsidy benefits are foregone as a deadweight loss. This expectation is borne out in figure 12, but an interesting aspect of the figure is that the decrease in subsidy benefits is much less pronounced for seed producer oligopoly power than for corn processor oligopsony. The reason is that higher seed prices charged due to upstream oligopoly power actually have a benefit to the downstream industry in terms of acting as a form of commitment device to enable the industry to move closer to the revenue-maximizing amount of corn production. Demand at the competitive equilibrium is inelastic in the simulation model based upon the Shonkwiler and Maddala (1985) estimate, and, thus, the industry is operating in the declining portion of the total revenue function. The decline in output caused by higher seed prices enables the industry to increase revenues from corn sales by moving to a higher point on the corn total revenue function.

Conclusion

No estimates have been provided regarding degrees of market power, if any, exercised in the corn sector, but the subject is discussed frequently in debates about subsidies for ethanol production and structural conditions in the industry create a prima-facie case for concerns about market power. The purpose of this paper was to construct a simple model of the corn sector that had maximum flexibility in terms of the types and magnitude of market power it could depict, in order to examine the impacts that market power would have on the market and distributional effects of the ethanol subsidy.

For reasonable parameterizations of the corn sector, the results demonstrated that the impacts on prices and output were limited for modest departures from competition. Distributional impacts were much greater. Given that a key political and policy objective of the

ethanol subsidy is to benefit corn producers, the fact that seed producers and corn processors capture relatively large shares of the benefits from the subsidy when they have market power is relevant to the policy debate.

A somewhat surprising result is that upstream oligopoly power exercised by seed producers is prospectively as important in influencing the positive and distributional impacts of the subsidy as the much more frequently discussed and debated prospect that downstream corn processors may exercise buyer power. Yet, as noted in the introduction, concentration among seed manufacturers is also relatively high, and genetically modified seeds with patented traits also can enhance market power in seed sales.

Elasticities of the relevant functions play a key role in influencing the distribution of benefits from the ethanol subsidy under perfect competition based upon the usual incidence analysis. Their effect is magnified in the presence of market power because the distorting impact of market power depends upon the elasticity of the underlying supply or demand function that is being exploited. The relative inelasticity of seed demand, which, as we noted, is due to the basic economics of derived demand, enables even modest oligopoly power in the seed sector to cause large increases in the seed price. The pernicious effect of this outcome on farmers and processors was offset somewhat in this model because higher input costs enable the corn industry to commit to reduce output and achieve higher total revenue, given inelastic corn demand.

Clearly much additional work can be done on this topic. High on this list would be to undertake econometric testing for market power in the corn sector. Such estimation will present many challenges. The conceptual model developed here might be extended in various dimensions including relaxation of the simplifying assumptions that seed production involved constant marginal cost and that corn processors sell competitively downstream. More extensive

simulations can also be performed with the present model, including exploring the impacts of different elasticities for corn supply, corn demand, and seed input demand.

Figure 1. Impact of Ethanol Subsidy when Downstream Buyers Have Oligopsony Power.

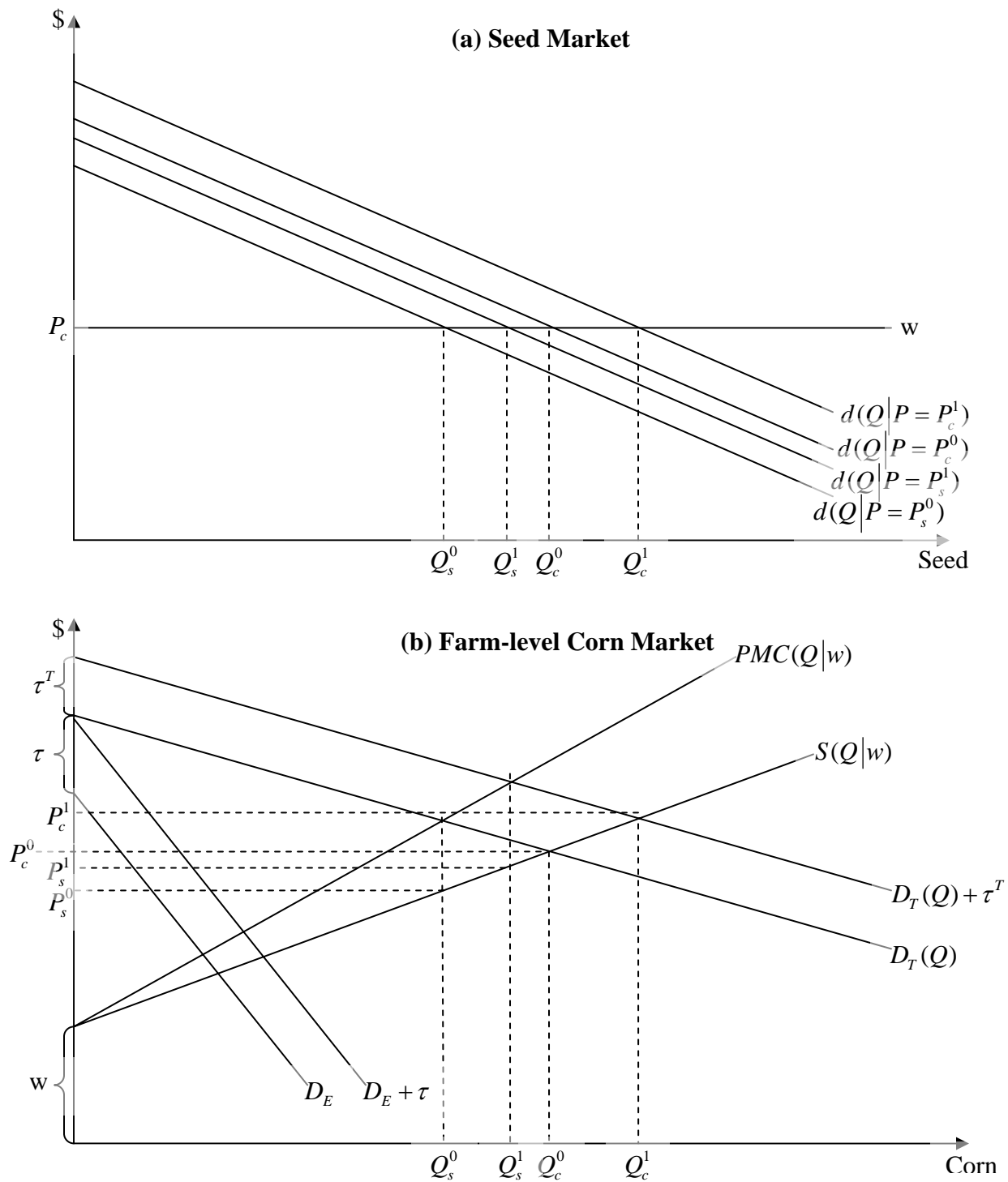


Figure 2. Impact of the Ethanol Subsidy when Upstream Sellers have Oligopoly Power.

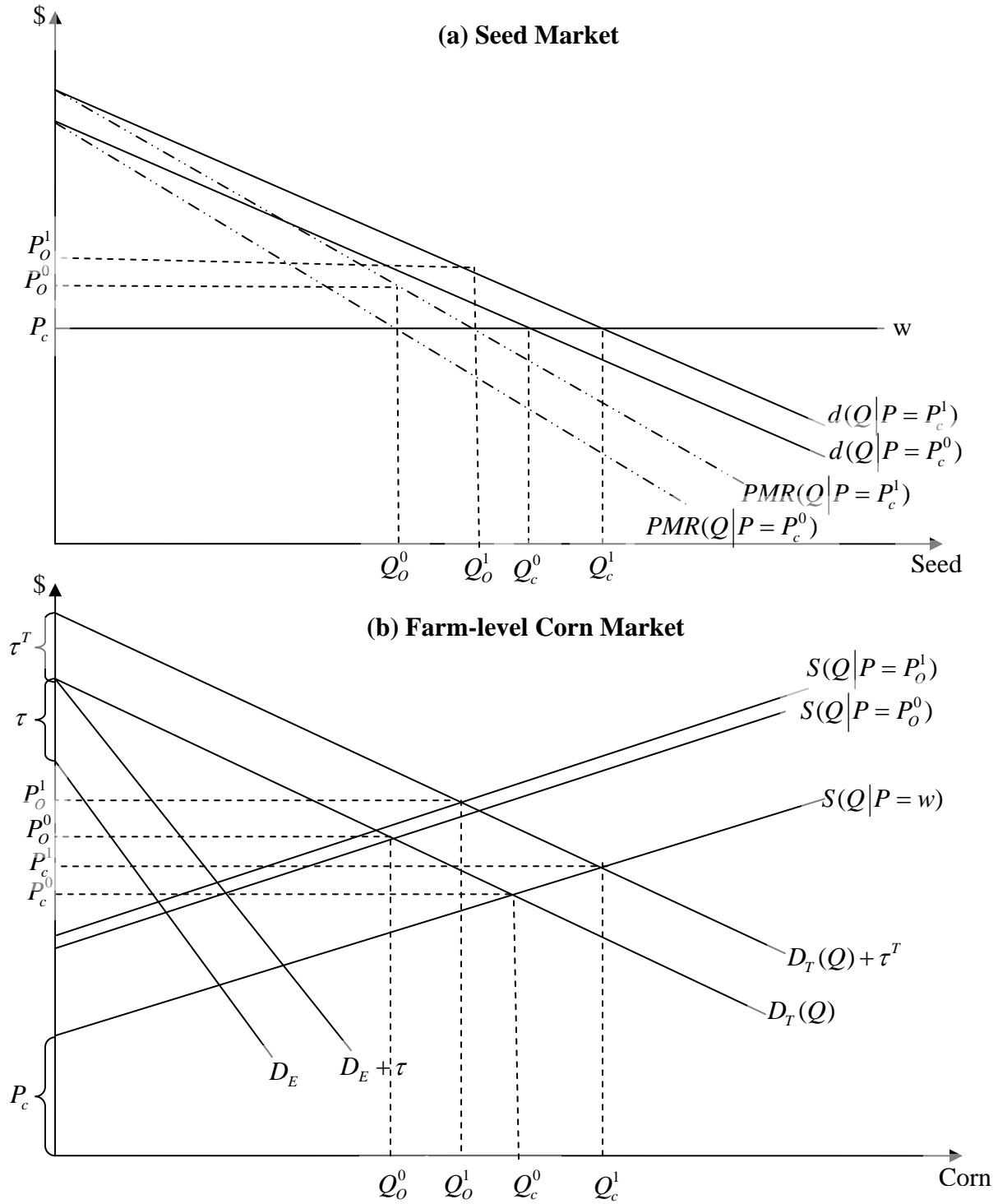


Figure 3. Impact of the Subsidy on the Price of Corn Under Market Power: Percentage Change Relative to Perfect Competition

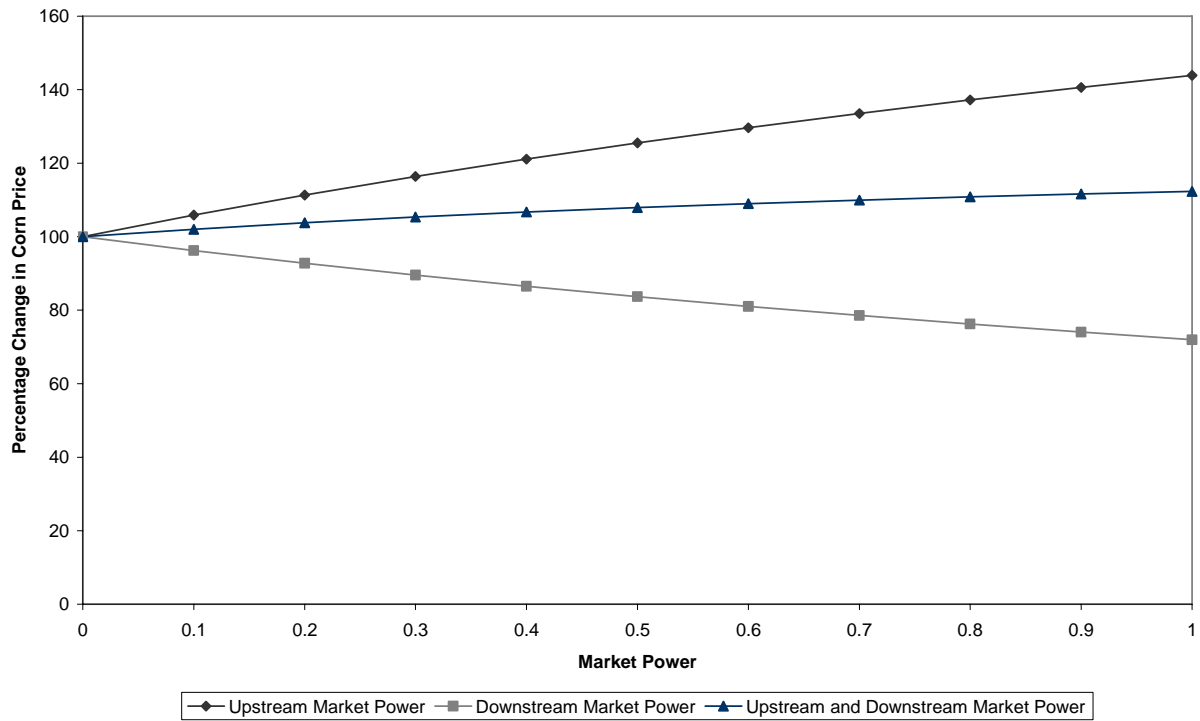


Figure 4. Impact of the Subsidy on the Gross Farm Margin Under Market Power: Percentage Change Relative to Perfect Competition

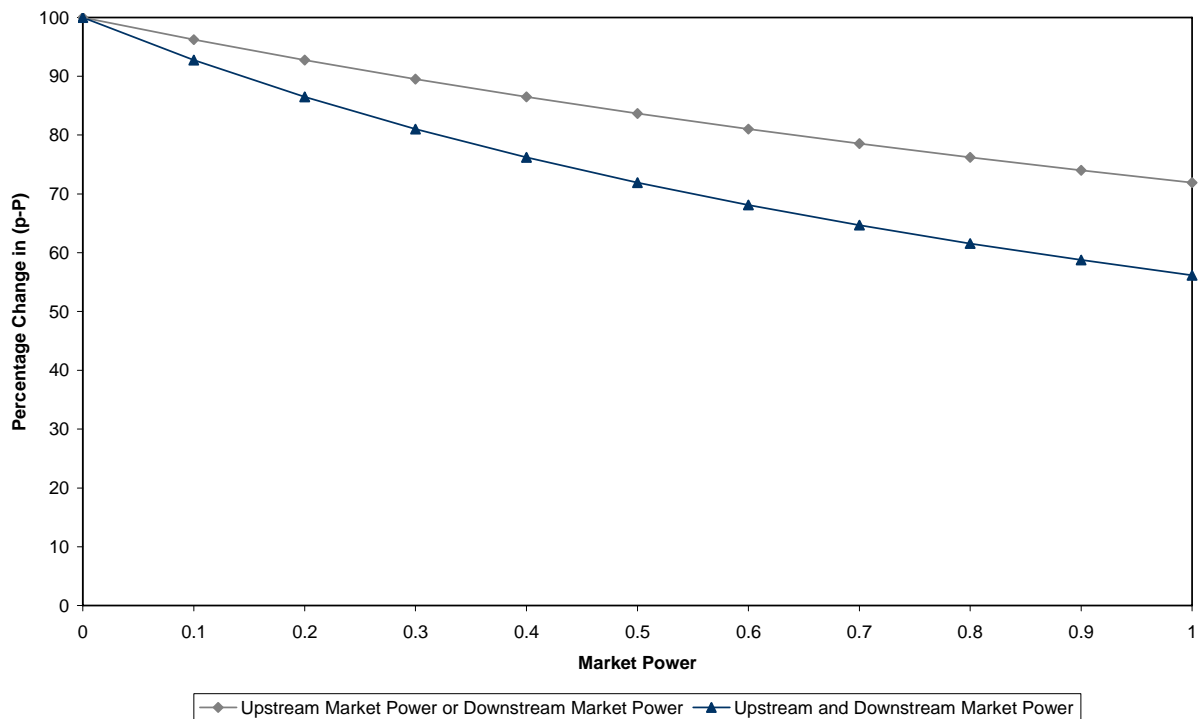


Figure 5. Impact of the Subsidy on Production of Corn Under Market Power: Percentage Change Relative to Perfect Competition

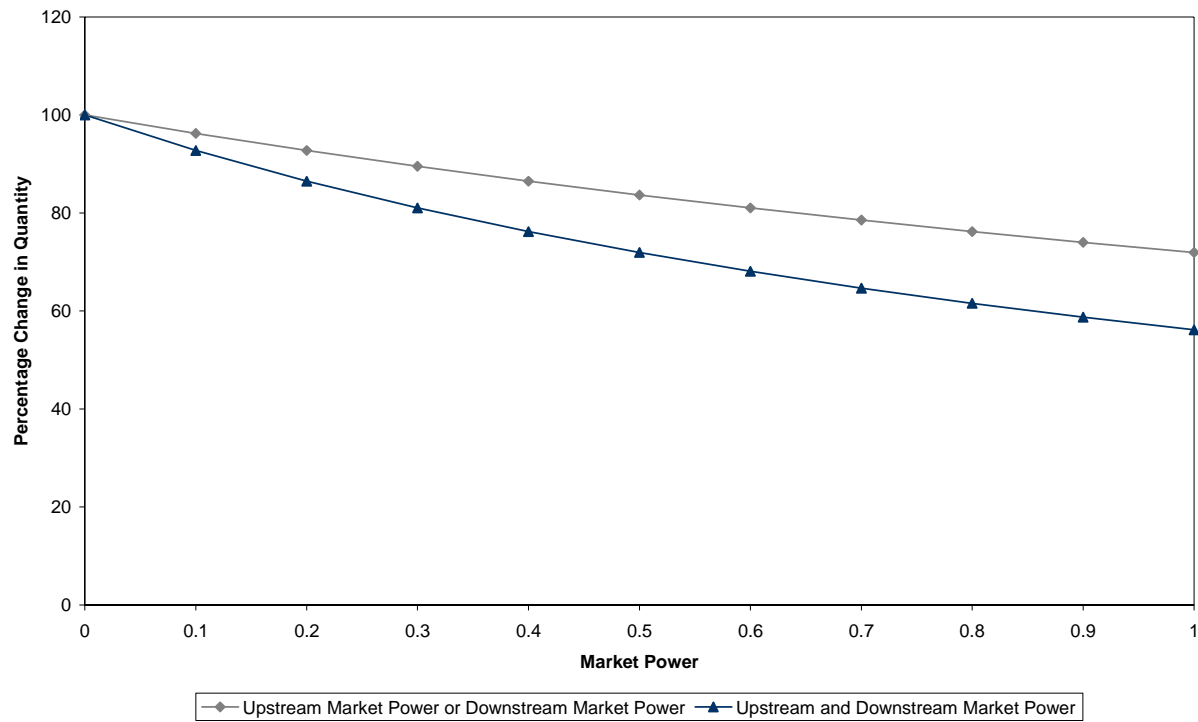


Figure 6. Change in Seed Producers', Farmers', and Corn Processors' Profits Due to the Subsidy for Seed Producer Oligopoly Power

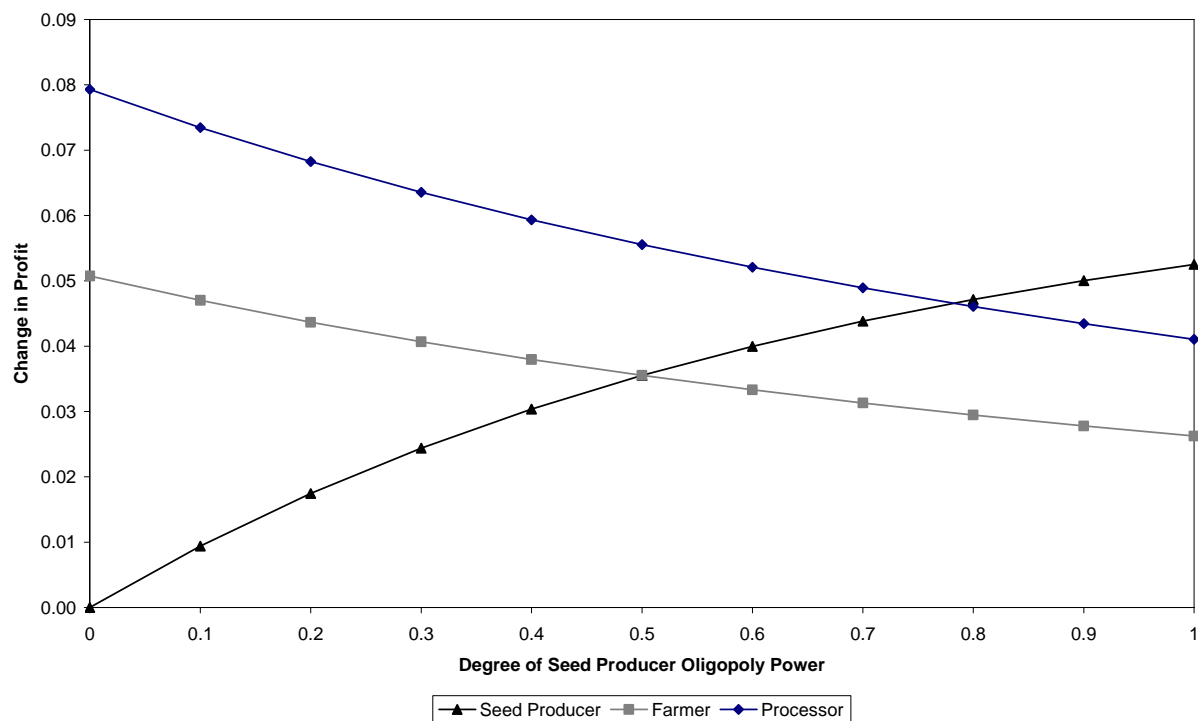


Figure 7. Change in Farmers' and Corn Processors' Profits Due to the Subsidy for Corn Processor Oligopsony Power

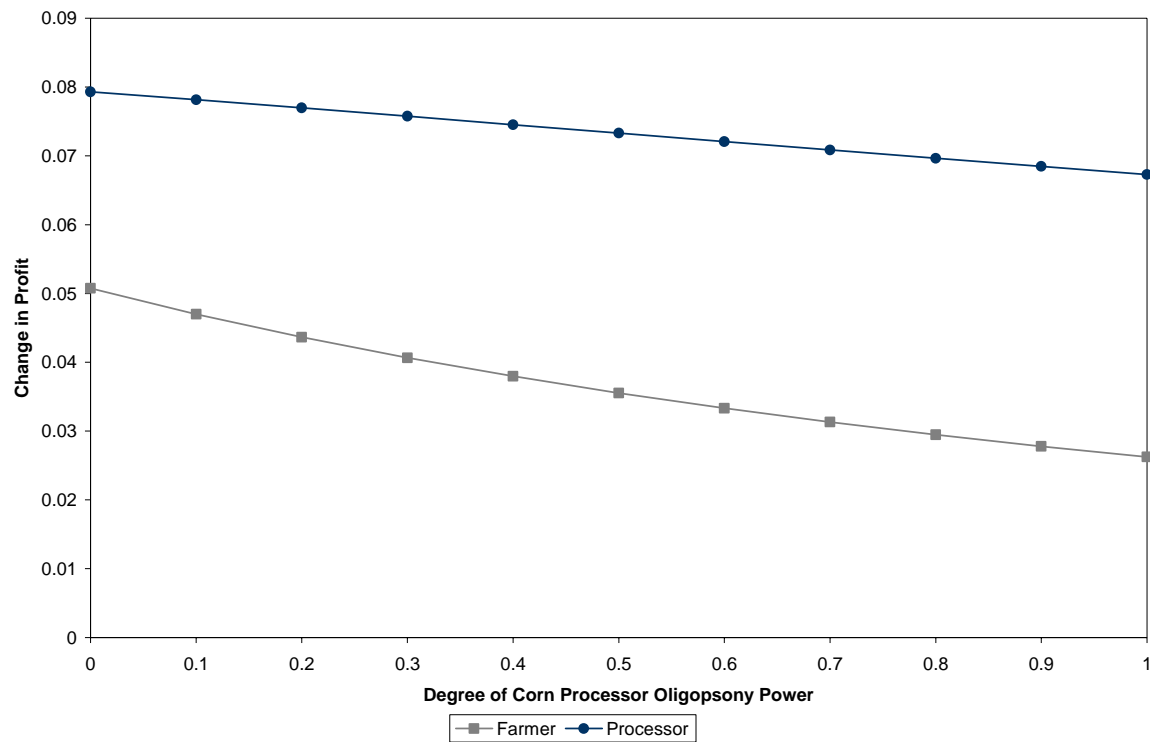


Figure 8. Change in Seed Producers', Farmers', and Corn Processors' Profits Due to the Subsidy for Both Oligopoly and Oligopsony Power

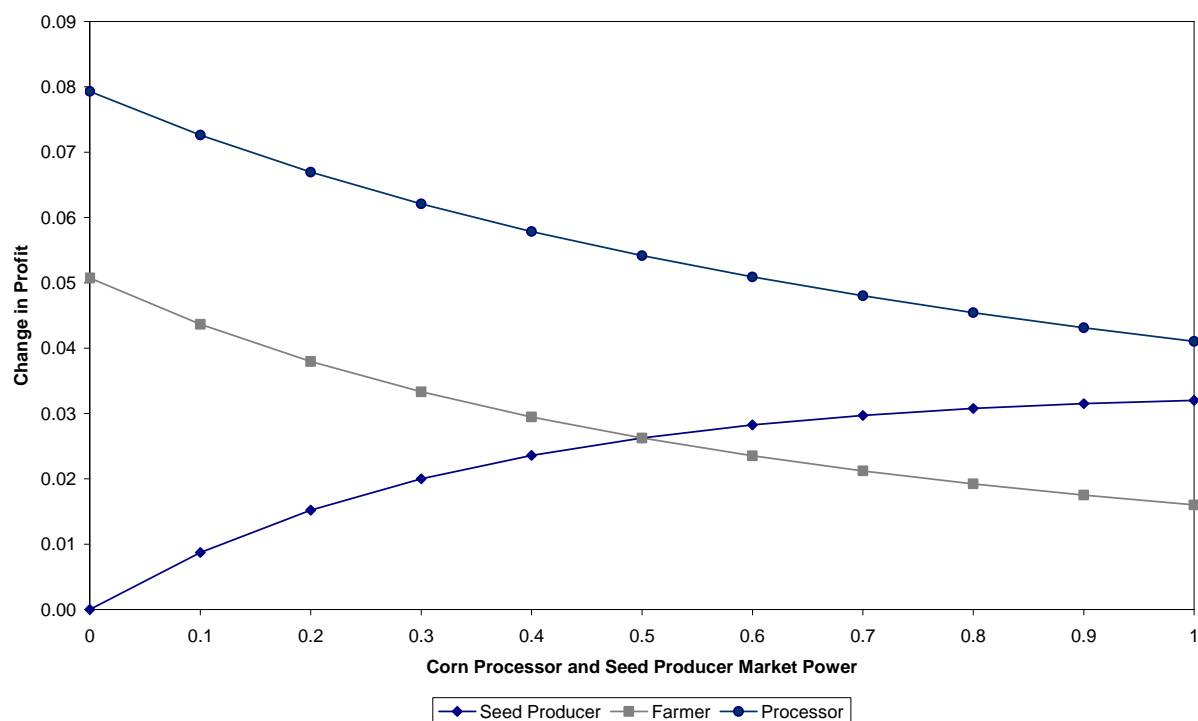


Figure 9. Share of the Benefit of the Subsidy Going to Seed Producers, Farmers, and Corn Processors Under Seed Producer Oligopoly Power

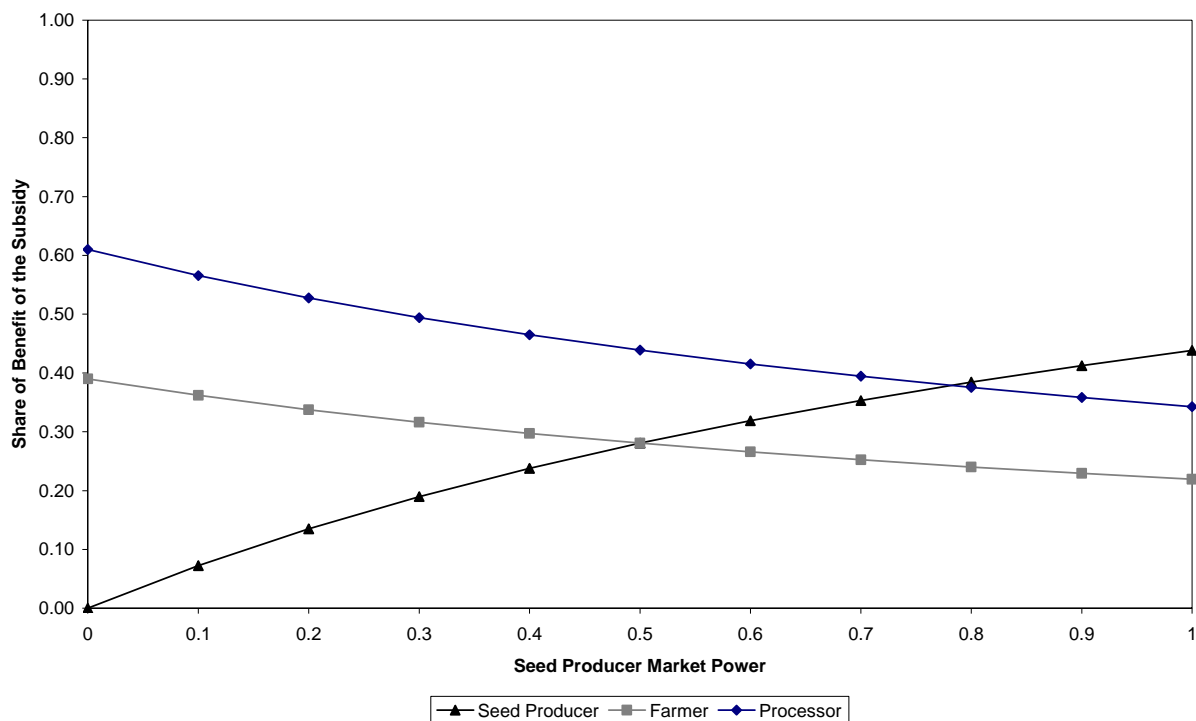


Figure 10. Share of Benefit of the Subsidy Going to Farmers and Corn Processors Under Corn Processor Oligopsony Power

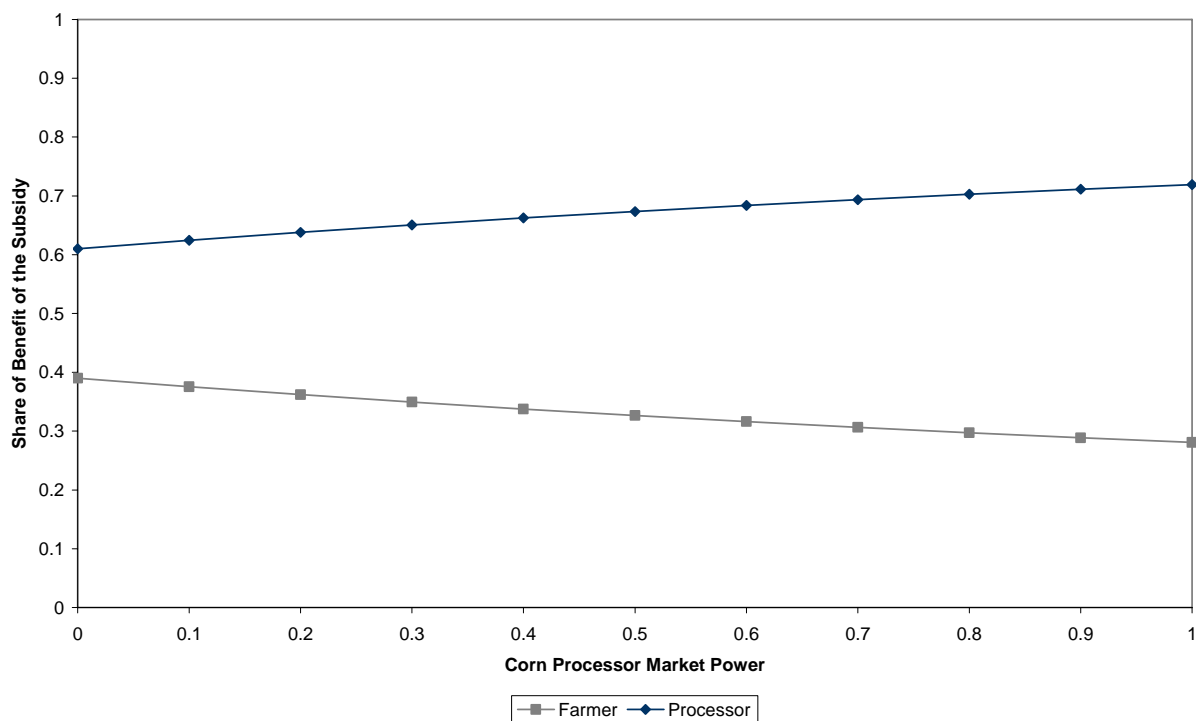


Figure 11. Share of the Benefit of the Subsidy Going to Seed Producers, Farmers, and Corn Processors Under Both Oligopoly and Oligopsony Power

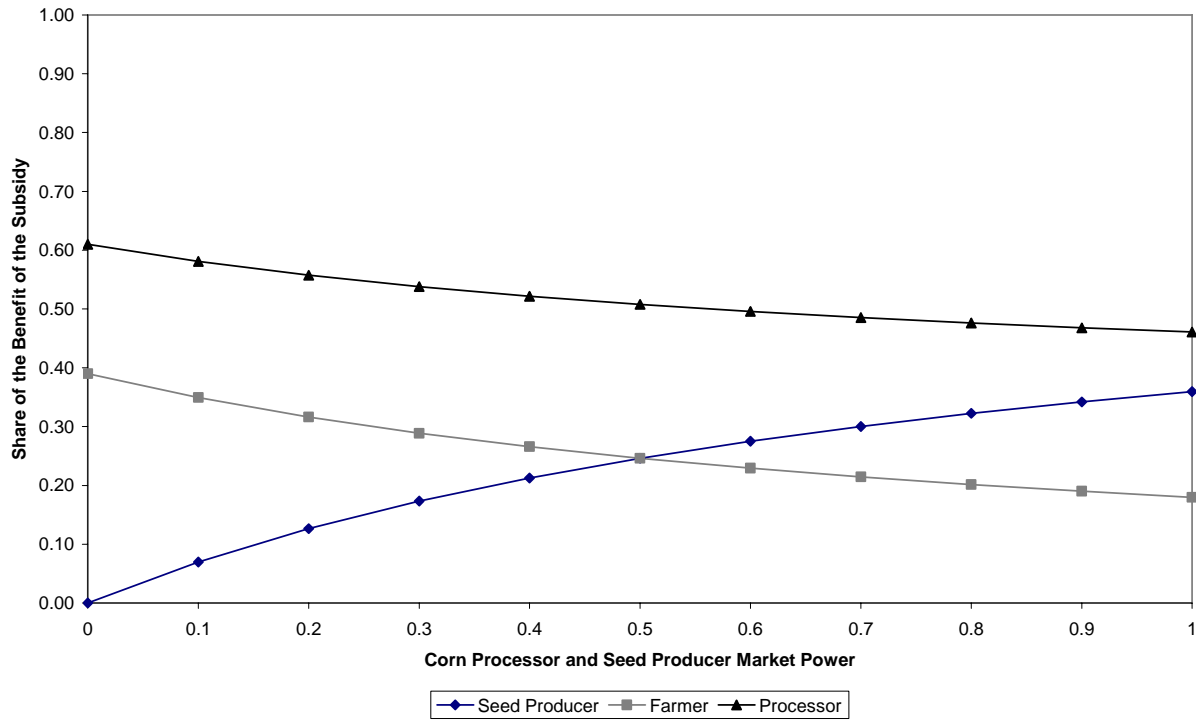
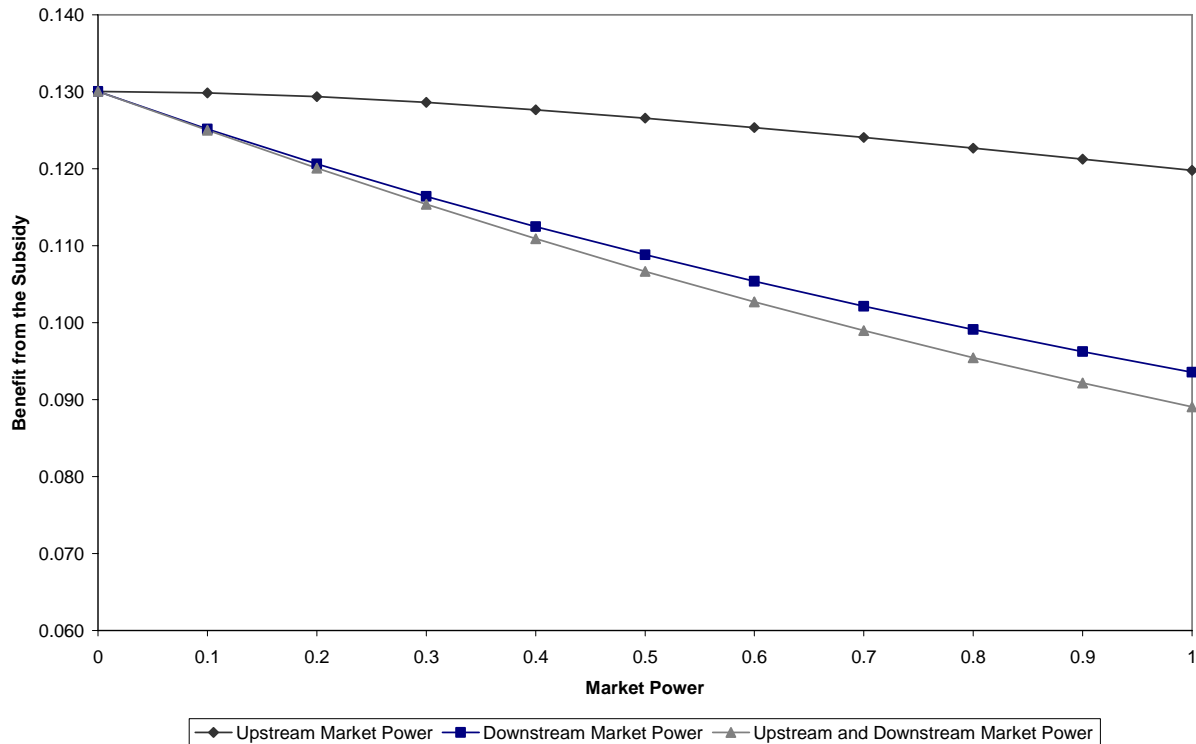


Figure 12. Subsidy Benefits as a Function of the Type and Degree of Market Power.



Appendix: Converting the Ethanol Subsidy to an All-Corn Basis

Begin with linear inverse farm-gate demand functions for corn for ethanol (market 1) and for all other uses (market 2):

$$\begin{aligned} p_1 &= a_1 + b_1 Q_1 + \tau \\ p_2 &= a_2 + b_2 Q_2 \end{aligned} ,$$

where corn used for ethanol receives a per-unit subsidy of τ . Writing the demands in their direct form, setting $p_1 = p_2$, and summing yields the following aggregate demand function:

$$Q = \frac{b_1 + b_2}{b_1 b_2} P - \frac{b_1 a_2 + b_2 a_1}{b_1 b_2} - \frac{b_2}{b_1 b_2} \tau .$$

Now consider imposing a per-unit subsidy, k , on all corn production. Then we have

$$\begin{aligned} p_1 &= a_1 + b_1 Q_1 + \tau^T \\ p_2 &= a_2 + b_2 Q_2 + \tau^T \end{aligned}$$

Writing the demands in their direct form, setting $p_1 = p_2$, and summing yields the following aggregate demand function for the all-corn subsidy case:

$$Q = \frac{b_1 + b_2}{b_1 b_2} P - \frac{b_1 a_2 + b_2 a_1}{b_1 b_2} - \frac{b_1 + b_2}{b_1 b_2} \tau^T .$$

For the subsidies to be equivalent, we need $(b_1 + b_2)\tau^T = b_2 \tau \rightarrow \tau^T = \tau b_2 / (b_1 + b_2)$, where

$$\frac{b_2}{b_1 + b_2} = \frac{Q_1(p - a_2)}{Q_2(p - a_1 - \tau) + Q_1(p - a_2)} .$$

The right-hand side of this expression converges to $Q_1 / (Q_1 + Q_2)$, i.e., the ethanol share of total corn production if $a_1 + \tau \approx a_2$, but this condition implies that ethanol is competitive with other uses as a demander of raw corn input, which is precisely the stated objective of policy makers in setting the subsidy.

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