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## **Market Power in the Corn Sector: How Does it Affect the Impacts of the Ethanol Subsidy?**

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# **Market Power in the Corn Sector: How Does It Affect the Impacts of the Ethanol Subsidy?**

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**Abstract:** Market power is discussed frequently in debates about subsidies for ethanol production. The structural conditions in the corn industry create a case for concerns about market power. This paper develops an analytical model for determining the production and price impacts and the distribution of benefits from the U.S. ethanol subsidy when upstream sellers in the seed sector and downstream buyers in the processing sector may exercise market power. Results demonstrate that the impacts on prices and output are limited for modest departures from competition. Distributional impacts are much greater. Seed producers and corn processors with market power are able to capture relatively large shares of the benefits of the subsidy.

**Keywords:** corn ethanol, market power, oligopoly, oligopsony, subsidy

## **Introduction**

The stated goals of the ethanol subsidy are to promote the diffusion of ethanol and to support farmers, who are believed to gain considerably through widespread adoption of ethanol produced from corn. Some consumers may also benefit from the subsidy through increased fuel supplies, lower fuel prices, and possible environmental benefits induced by the subsidies. However, consumers of other products, notably foods, are likely to be harmed by higher prices (Rajagopol et al.).

A growing literature investigates the benefits derived from the U.S. corn ethanol subsidy. All of these studies have utilized a competitive markets framework. Taheripour and Tyner analyze how the benefits of the ethanol subsidy are allocated among farmers, ethanol producers, fuel blenders, and land owners. They show that as the market for ethanol grows and accounts for a larger share of the corn market purchases, farmers will capture an increasing portion of the benefits associated with the ethanol subsidy. Gardner uses simulation analysis to show that corn growers benefit more from the subsidy than ethanol producers and consumers combined.<sup>1</sup> Schmitz, Moss, and Schmitz analyze the welfare impacts and distributional effects of the direct subsidies given to corn producers and the indirect subsidies received by ethanol processors in the U.S. They show that in an open-economy setting there may be benefits associated with using tax credit subsidies as opposed to direct payments to corn farmers.

Critics of the subsidy, ranging from popular commentators, such as editorialists at the *Wall Street Journal* and *Investor's Business Daily* (Bandow), to noted economists such as Stiglitz, have claimed that Archer, Daniels, Midland (ADM), a major ethanol producer, is the primary beneficiary of the subsidy. The benefits of a subsidy are distributed among participants in the market chain even under the competitive paradigm based upon standard tax/subsidy

incidence analysis, but it is not clear that as a competitive buyer and seller ADM could capture much, if any, of the subsidy benefit instead of passing it downstream to buyers or upstream to corn farmers. Thus, those who argue that ADM is a primary beneficiary of the subsidy ascribe, at least implicitly, to a model where ADM exercises market power in its procurement of corn for ethanol production or in the sale of ethanol, or both.

Indeed, the presence of powerful grain processors downstream like ADM and Cargill raises questions as to whether the competitive paradigm is appropriate to model this industry and whether analyses that rely upon this assumption are able to capture the true distribution of benefits from ethanol subsidies. In addition to the potential for market power downstream, concentration in the essential upstream corn seed sector is high and consistent with seller oligopoly power. The extensive use of protected GM seed traits may also confer monopoly power to the innovating seed producers. These considerations raise the question of whether and to what extent sellers upstream from the farm sector may be able to capture benefits from the subsidization of ethanol production.

This paper develops an analytical 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 from the farm in the corn-processing sector. It is not the goal of the 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 the subsidization. This paper thus contributes to the ongoing debate concerning the contentious policy. The substantial market

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<sup>1</sup> These authors' assumption of perfect competition is consistent with most studies analyzing agricultural policies (Sexton and Lavoie; McCorriston; Sexton et al.).

concentration and subsidies observed in the U.S. for ethanol production exist elsewhere as well, so we anticipate that the results from this paper also apply broadly to other countries.

The model draws upon the framework developed by Huang and Sexton (HS) and Alston, Sexton, and Zhang (ASZ). HS and ASZ developed models of buyer and seller market power exercised by downstream processing firms to determine the effect of imperfect competition on research benefits. Sexton et al. extended this model to study market power exercised at successive downstream stages. Related frameworks have been developed by other authors, including McCorrison, studying downstream oligopoly power, and Tadesse Weldegebriel, studying downstream oligopoly and oligopsony power, to show how market power distorts price transmission between the farm and downstream markets.

Our model extends this general framework and contributes to the literature on impacts of market power by incorporating possible seller power upstream from the farm sector and buyer power downstream from the farm in the corn-processing sector and by providing a specific application to ethanol subsidies. As noted, previous work based upon HS-ASZ and related models has focused exclusively on market power in the sector(s) downstream from the farm.

This paper proceeds with a brief background on ethanol and discussion of the industry structure. The model of imperfect competition is then developed and comparative static results are derived. This 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 U.S. Ethanol Industry**

Biofuels have generated a great deal of interest among developed and developing countries as a way to simultaneously reduce carbon emissions and imports of petroleum. Heightened concerns about global climate change, expanding demand for energy, increasing oil prices, and instability in oil-exporting countries have led to 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.

Ethanol has historically been unable to compete with petroleum. Therefore, governments have implemented subsidy programs to enhance the competitiveness of ethanol with fossil fuels and stimulate ethanol production. In the U.S., the Energy Policy Act of 2005 (EPACT 2005) establishes a renewable fuels standard which requires the use of 7.5 billion gallons of renewable fuel by 2012. The EPACT 2005 also reauthorizes a \$0.51 per gallon income tax credit to fuel blenders for each gallon of ethanol blended into gasoline.<sup>2</sup> Estimates of the total dollar value of the ethanol tax credit have been consistently revised upward (Koplow). The Joint Economic Committee on Taxation revised an estimate of \$1.44 billion annually for 2005-09 to \$2.22 billion annually for 2006-10, while the U.S. Treasury estimated an annual average tax expenditure of \$2.65 billion over 2005-11. Koplow indicates that the value of the tax credit will rise to \$3.8 billion annually by 2012, if the U.S. meets its renewable fuels standard mandates, as is expected.<sup>3</sup>

In 2007, ethanol production capacity in the U.S. totaled 7.4 billion gallons per year with another six billion gallons of capacity under construction. ADM owns in excess of 1 billion

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<sup>2</sup> An additional tax credit of \$0.10 per gallon is available to small ethanol producers (annual production less than 60 million gallons) on the first 15 million gallons they produce. Koplow estimates that the tax expenditure from this subsidy will be \$130 million for ethanol in 2008.

<sup>3</sup>The total cost of ethanol subsidies in the U.S. at all levels of the supply chain, including state and federal programs, encompassing support for output, factors of production, intermediate goods, and consumption, was estimated to be \$5.1 billion in 2006 (Koplow).

gallons of capacity. 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). However, the planned 2008 acquisition of US BioEnergy Corporation by Verasun Energy Corporation, the next largest producer, is expected to yield a firm with capacity just greater than that of ADM.

If we broaden the product market category to include all wet corn processing (the category most relevant to questions of oligopsony power in corn procurement), the four leading firms, ADM, Cargill, A.E. Staley, and CPC International, held a combined 74 percent market share in 1997 (MacDonald and Denbaly). 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 relevant procurement markets is higher than the national figures indicate.<sup>4</sup>

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. In addition, market power may be attained or enhanced through collusive behavior. It is significant in this regard that ADM was convicted in 1998 for colluding to fix prices to buyers of corn products (Connor).<sup>5</sup> Evidence of concern about competitiveness of corn procurement by U.S. antitrust authorities is provided by the U.S. Department of Justice’s requirement in 1999 of divestitures in Cargill’s acquisition of Continental Grain Company to prevent the combining firms from artificially depressing prices to farmers for corn, wheat and

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<sup>4</sup> Connor et al. classified food processing industries with four-firm concentration ratios (CR4) of 80% or more as “shared monopolies”,  $65 \leq CR4 < 80$  as “highly concentrated oligopolies”,  $50 \leq CR4 < 65$  as “moderately concentrated oligopolies”, and  $35 \leq CR4 < 50$  as “low-grade oligopolies”. Although Connor et al. were concerned with seller power, presumably they would apply their classification to buyer power as well, with the caveat that national concentration rates understate the true level of concentration when procurement markets are local or regional in geographic scope.

soybeans. Thus, the downstream industry's high concentration, localized farm procurement markets for corn, and track record of collusive behavior all give reasons for concern that corn-products manufacturers may exercise market power in procuring the raw product from farmers.

Upstream from the farm sector, four firms, DuPont, Monsanto, Novartis and Dow, accounted for 69 percent of corn seed sales in the U.S. (MacDonald and Denbaly). Sixty percent of the 2006 corn crop was planted using genetically modified seed, and the percentage is expected to continue increasing. Innovation and growing reliance on genetically modified seed are likely to increase corn seed industry concentration and market power (Barton; Mansfield 1962, 1983). R&D generally allows large firms to extend their profit advantage over smaller firms (Rosen), and innovating firms achieve limited monopoly status through intellectual property rights, enabling them 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 farmers, may be largely captured by innovating firms (e.g., Moschini and Lapan).

### **The Model**

To enable the model to be as general as possible in terms of its depiction of alternative levels of upstream and downstream competition, we simplify other aspects of it. In particular, we assume that corn seed is used in fixed proportion in corn production, and, in turn, that corn is used in fixed proportions in producing various corn products downstream. Without further loss of generality, through choice of measurement units for the various quantities, the Leontief coefficients can be set to 1.0 for converting corn seed to corn production and corn into corn

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<sup>5</sup> The other major corn processors were not charged in the criminal price-fixing case, but Cargill and A.E. Staley, along with ADM, were sued in civil court for fixing the price of high fructose corn syrup. Cargill, without admitting liability, settled its case for \$24 million. See Connor for further discussion of the price-fixing allegations.

products. Further, we abstract from heterogeneity among firms and possible product differentiation and work instead with a representative firm at each vertical stage.

Consider first the farm sector. Farmers are assumed to buy and sell competitively. A representative farmer's profit maximization problem is:

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

where  $p$  is the farm price for corn,  $P$  is the price for corn seed,  $q$  is the farmer's corn output and seed input,  $c(q|\mathbf{V})$  represents costs for other inputs into corn production that do not necessarily enter production in fixed proportion, and  $\mathbf{V}$  is the vector of fixed prices for these inputs. We assume  $\partial c / \partial q = MC(q|\mathbf{V}) > 0$ , and  $\partial^2 c / \partial q^2 > 0$ . The first order condition to (1) is

$$(2) \quad (p - P) = MC(q|\mathbf{V}).$$

The second-order condition is necessarily satisfied, given prior assumptions. Equation (2) can be solved to yield the representative farmer's supply function,  $q = s(p - P|\mathbf{V})$ , where

$s(\cdot) = MC^{-1}(\cdot)$ . Given  $n$  homogeneous farmers, market supply of corn is

$$(3) \quad Q = ns(p - P|\mathbf{V}) = S(p - P|\mathbf{V}),$$

where  $\partial S / \partial p > 0$ , given the assumptions on  $c(q|\mathbf{V})$ , and  $\partial S / \partial P = -\partial S / \partial p < 0$ . It will be convenient to also depict the corn supply function in its inverse form,  $p(Q, P|\mathbf{V}) = P + M(Q|\mathbf{V})$ , where  $M' > 0$ . Given fixed proportions between corn seed and corn production, (3) also represents the input demand for corn seed, which is represented in its inverse form as  $P(Q, p|\mathbf{V}) = p - M(Q|\mathbf{V})$ . Various derivative relationships hold among these interrelated functions, which are routine, but nonetheless worth mentioning because they are useful in signing subsequent comparative static expressions:

$$\frac{\partial P(\cdot)}{\partial p} = \frac{\partial p(\cdot)}{\partial P} = 1, \quad \frac{\partial S(\cdot)}{\partial p} = \frac{1}{\partial p(\cdot)/\partial Q} = \frac{1}{\partial M/\partial Q} = -\frac{\partial S(\cdot)}{\partial P} = -\frac{1}{\partial P(\cdot)/\partial Q}.$$

The latter set of equalities follows from properties of the inverse of a monotonic function and the fixed-proportions relationship between seed input and corn output.

Now consider the corn processing sector. Although processing activities can take place across several vertical stages, we consider a consolidated processing sector whose activities include producing ethanol and blending ethanol with petroleum to produce motor fuel. We abstract away from unproductive complications caused by multi-product production by assuming that processors produce a composite corn product that includes ethanol and other products at their current market shares. Define

$$(4) \quad f = f(Q|\mathbf{X}), f'(Q) < 0,$$

as the aggregate inverse demand of downstream users for the composite processed commodity, where  $\mathbf{X}$  is a vector of variables that shift downstream demand for processed corn products.

The integrated processors receive the per-unit subsidy on ethanol blended to produce motor fuel in this model. The subsidy shifts the processing sector's willingness to pay for corn at the farm-level but in a way that depends upon the relative importance of ethanol production as part of total corn demand. Given the composite corn product, let  $\tau$  denote the per-unit value of the subsidy as it applies to total corn product, not just corn used for ethanol.<sup>6</sup> We derive  $\tau$  in the appendix for the current subsidy level and mix of products produced from corn, based upon the parameterizations used in the simulation model.

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<sup>6</sup> The fact that the ethanol subsidy affects the farm demand for all corn, regardless of its end use, is a consequence of simple arbitrage among alternative processed product forms for corn. The subsidy for ethanol has caused the mix of corn products to shift in favor of ethanol production at the expense of other uses for corn. This change in the mix of corn products has been discussed elsewhere (U.S. Department of Agriculture, Food and Agricultural Policy Research Institute), but it plays no role in our analysis, and thus we work simply with the composite corn product that embodies the current distribution of outputs and then apply the subsidy to the composite output.

We again work with a representative firm and assume a constant returns processing technology such that marginal processing costs, excluding costs of procuring corn, are a constant,  $b$ , per unit of composite output produced. Processors sell corn products, including ethanol-blended fuels, downstream to powerful buyers who we assume are able to countervail any attempts by the processors to exercise selling power.<sup>7</sup> Thus, processors are modeled as competitive sellers who treat output price,  $f$ , of the composite processed product as parametric.

The representative processor's optimization problem is thus

$$(5) \quad \underset{\{q\}}{\text{Max}} \quad \Pi = (f + \tau)q - (P + b)q - M(Q|\mathbf{V})q.$$

The first-order condition to (5) can be expressed in the following form (HS, ASZ):

$$(6) \quad f + \tau - b - P = M(Q|\mathbf{V}) \left[ 1 + \frac{\theta}{\varepsilon} \right],$$

where  $\theta \in (0,1]$  is the oligopsony market power parameter (also called conjectural elasticity),

$\varepsilon = 1 / \left( \frac{\partial M}{\partial Q} \frac{Q}{M} \right)$ , and  $(\partial M / \partial Q)(Q / M)$  is the elasticity (or flexibility) of the  $M(\cdot)$  function

evaluated at the market equilibrium.<sup>8</sup> The greater is  $\theta$ , the greater is the market power of the oligopsony buyers, with  $\theta = 1$  representing pure monopsony behavior or perfect collusion, and  $\theta \rightarrow 0$  denoting convergence to perfect competition. Given the assumptions of homogeneous processors, constant-returns and fixed-proportions technology, equation (6) defines a supply relationship for the composite corn product and input demand relationship for corn at the farm.

Substituting (4) into (6) yields the equilibrium condition in the processing sector:

<sup>7</sup> This assumption is consistent with the recent U.S. Federal Trade Commission analysis, which concluded “the level of concentration in ethanol production would not justify a presumption that a single firm or small group of firms, could yield sufficient market power to set prices or coordinate on prices or output (pp. 2-3)”.

<sup>8</sup>  $\varepsilon$  is directly correlated with but is not identical to the price elasticity of corn supply:

$\varepsilon_s = (1 / \partial M / \partial Q)[(P + M) / Q] > \varepsilon$ . The difference is important because oligopsony power can be exercised only with respect to the portion of the corn supply that is due to inputs other than seed. In essence, the portion of corn supply due to the seed input is perfectly elastic.

$$(7) \quad f(Q|\mathbf{X}) + \tau - b - P = M(Q|\mathbf{V}) \left[ 1 + \frac{\theta}{\varepsilon} \right].$$

Finally, consider the upstream seed corn sector. We assume that homogeneous seed firms operate with constant marginal cost,  $w(\mathbf{Z})$ , where  $\mathbf{Z}$  denotes exogenous variables, such as input prices, that shift seed manufacturer marginal costs. The market demand for seed is given by (3) or in inverse form by  $P(Q, p|\mathbf{V}) = p - M(Q|\mathbf{V})$ . The optimization problem for the representative seed manufacturer can be expressed as

$$(8) \quad \underset{(q)}{\text{Max}} \quad \Omega = [p - M(Q|\mathbf{V})]q - w(\mathbf{Z})q.$$

The first-order condition to (8) can be written as

$$(9) \quad p - M(Q|\mathbf{V}) \left[ 1 + \frac{\xi}{\varepsilon} \right] = w(\mathbf{Z}),$$

where the parameter  $\xi \in (0, 1]$  indicates the degree of seller market power. Higher values of  $\xi$  denote greater levels of selling power in the corn seed industry, with  $\xi = 1$  representing the case of pure monopoly behavior, and  $\xi \rightarrow 0$  depicting convergence to perfect competition. Equation (9) represents the equilibrium condition in the seed sector, given the assumptions of the model.

Equilibrium in this vertical market model of the corn sector is defined by equations (3)—farm corn supply and seed input demand, (4)—downstream demand for processed corn products, (7)—processing-sector equilibrium condition, and (9)—corn-seed-sector equilibrium condition. Given parameterizations for farm supply and downstream market demand, the system can be solved for equilibrium values of the endogenous variables,  $f$ ,  $p$ ,  $P$ , and  $Q$  as functions of the exogenous parameters,  $\tau$ ,  $\theta$ , and  $\xi$ , the parameters characterizing the farm-supply and downstream-demand functions, and the exogenous variables that shift farm supply ( $\mathbf{V}$ ), downstream demand ( $\mathbf{X}$ ), and seed manufacturer costs ( $\mathbf{Z}$ ). We subsequently pursue this strategy

via a simulation model in order to quantify the impacts of market power on the market equilibrium and distribution of benefits from the subsidy, but first consider insights obtainable from the general model.

Comparative statics from the model can be found by totally differentiating (3), (4), (7), and (9) with respect to any of the aforementioned exogenous factors. Of most direct concern are the impacts of the ethanol subsidy,  $\tau$  :

$$(3') \quad \frac{dQ^*}{d\tau} = \frac{\partial S}{\partial p} \frac{dp^*}{d\tau} - \frac{\partial S}{\partial P} \frac{dP^*}{d\tau},$$

$$(4') \quad \frac{df^*}{d\tau} = \frac{\partial f}{\partial Q} \frac{dQ^*}{d\tau},$$

$$(7') \quad \frac{\partial f}{\partial Q} \frac{dQ^*}{d\tau} + 1 - \frac{dP^*}{d\tau} = \left[ \frac{\partial M}{\partial Q} \frac{dQ^*}{d\tau} \right] \left( 1 + \frac{\theta}{\varepsilon} \right) - M(Q^*) \frac{\theta}{\varepsilon^2} \frac{d\varepsilon}{d\tau},$$

$$(9') \quad \frac{dp^*}{d\tau} - \left[ \frac{\partial M}{\partial Q} \frac{dQ^*}{d\tau} \right] \left( 1 + \frac{\xi}{\varepsilon} \right) - M(Q^*) \frac{\xi}{\varepsilon^2} \frac{d\varepsilon}{d\tau} = 0,$$

where star superscripts are used to denote equilibrium values.

The system of equations comprised by (3'), (4'), (7'), and (9') can be rewritten in matrix form as

$$(10) \quad \begin{bmatrix} 1 & -\frac{\partial S}{\partial p} & \frac{\partial S}{\partial P} & 0 \\ -\frac{\partial f}{\partial Q} & 0 & 0 & 1 \\ \frac{\partial f}{\partial Q} - \frac{\partial M}{\partial Q} \left(1 + \frac{\theta}{\varepsilon}\right) & 0 & -1 & 0 \\ -\frac{\partial M}{\partial Q} \left(1 - \frac{\xi}{\varepsilon}\right) & 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} \frac{dQ^*}{d\tau} \\ \frac{dp^*}{d\tau} \\ \frac{dP^*}{d\tau} \\ \frac{dF^*}{d\tau} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ -\left(1 + M(Q^*) \frac{\theta}{\varepsilon^2} \frac{d\varepsilon}{d\tau}\right) \\ M(Q^*) \frac{\xi}{\varepsilon^2} \frac{d\varepsilon}{d\tau} \end{bmatrix}.$$

In (10),  $\frac{\partial S(\cdot)}{\partial p} = -\frac{\partial S(\cdot)}{\partial P} > 0$  is the slope of corn supply function and minus the slope of the corn

seed demand function,  $\frac{\partial M}{\partial Q} > 0$  is the slope of the inverse corn supply function and minus the

slope of the corn seed demand function,  $\frac{\partial f(\cdot)}{\partial Q} < 0$  is the slope of the aggregate demand for

processed corn products,  $\frac{d\varepsilon}{d\tau}$  is the effect of a small change in the subsidy on the elasticity,  $\varepsilon$ ,

evaluated at equilibrium.

All of these expressions are straightforward in their interpretation except for  $\frac{d\varepsilon}{d\tau}$ . This elasticity effect is present in analyses of imperfectly competitive market equilibria because an exogenous shock may affect the distortions caused by market power through the impact of the distortion on the elasticity of the underlying demand or supply curve that is being exploited. The distortion caused by market power is determined jointly by this elasticity and the degree of market power, as demonstrated in equations (7) and (9). Thus, any shock that causes corn supply or seed demand to become more inelastic at equilibrium exacerbates the distortion caused by market power, and vice versa for shocks that make these curves more elastic at equilibrium. In general, for modest shocks and well-behaved demand or supply functions, this effect is small.

Accordingly, to simplify the comparative static analysis, we assume  $\frac{d\varepsilon}{d\tau} = 0$ , and also invoke the simplifications discussed previously, in which case the comparative static results with respect to the ethanol subsidy can be expressed as:

$$(11) \quad \begin{bmatrix} \frac{dQ^*}{d\tau} \\ \frac{dp^*}{d\tau} \\ \frac{dP^*}{d\tau} \\ \frac{df^*}{d\tau} \end{bmatrix} = \frac{1}{D} \begin{bmatrix} \frac{\partial S}{\partial P} \varepsilon \\ -(\xi + \varepsilon) \\ -\xi \\ \frac{\partial S}{\partial P} \frac{\partial f}{\partial Q} \varepsilon \end{bmatrix}$$

where  $D = -(\varepsilon + \theta) - \frac{\partial S}{\partial P} \frac{\partial f}{\partial Q} - \xi < 0$ .<sup>9</sup> Consequently, the comparative static results can be signed

as follows:  $\frac{dQ^*}{d\tau} > 0$ ,  $\frac{dp^*}{d\tau} > 0$ ,  $\frac{dP^*}{d\tau} \geq 0$ , and  $\frac{df^*}{d\tau} < 0$ .

It is interesting to determine how market power influences the impacts of the subsidy. These impacts are found by differentiating (11) with respect to  $\xi$  and  $\theta$ . The effects of oligopoly

power in the seed sector on the impacts of the subsidy are as follows:  $\frac{\partial^2 Q^*}{\partial \tau \partial \xi} < 0$ ,  $\frac{\partial^2 P^*}{\partial \tau \partial \xi} > 0$ , and

$\frac{\partial^2 f^*}{\partial \tau \partial \xi} > 0$ . The sign of  $\frac{\partial^2 p^*}{\partial \tau \partial \xi}$  is ambiguous. Oligopoly seed manufacturers capture part of the

subsidy benefit through charging a higher seed price, which causes the corn supply function to

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<sup>9</sup> If  $\frac{d\varepsilon}{d\tau} > 0$ , the comparative static results described in the paper hold and are reinforced. If  $\frac{d\varepsilon}{d\tau} < 0$  and the effect is large enough, the signs of the comparative static results could be reversed. These perverse results would occur if the shock caused by the subsidy moved the equilibrium to a point on the corn supply or seed demand functions that was sufficiently more inelastic to cause the effect of the increase in the market-power distortion on corn production and seed demand to dominate the output- and input-expanding effect of the subsidy.

shift inward, resulting in less corn production. Downstream consumers pay a higher price because reduced corn production reduces production of processed corn products. The effect of  $\xi$  on  $p$  is ambiguous because market power in the seed sector induces offsetting effects on corn prices. Given  $\frac{\partial^2 Q^*}{\partial \tau \partial \xi} < 0$ , less output expansion occurs due to the subsidy, which mitigates the increase in the corn price, ceteris paribus, but because  $\frac{\partial^2 P^*}{\partial \tau \partial \xi} > 0$ , higher seed prices shift back the corn supply curve, causing higher  $p$ , ceteris paribus.

The effects of oligopsony power in the seed sector on the impacts of the subsidy are as follows:  $\frac{\partial^2 Q^*}{\partial \tau \partial \theta} < 0$ ,  $\frac{\partial^2 p^*}{\partial \tau \partial \xi} < 0$ , and  $\frac{\partial^2 f^*}{\partial \tau \partial \theta} > 0$ . The sign of  $\frac{\partial^2 P^*}{\partial \tau \partial \theta}$  is ambiguous. Corn processors with market power capture a portion of the subsidy benefit by curtailing the expansion in output caused by the subsidy relative to perfect competition, thereby limiting the increase in price of corn at the farm, and the decrease in price for corn products received by downstream users. The impact of oligopsony power on the seed price is ambiguous due to offsetting effects. The reduced output expansion caused by oligopsony power causes less movement down the seed demand curve, ceteris paribus, implying higher  $P$ , but given  $\frac{\partial^2 p^*}{\partial \tau \partial \theta} < 0$ , the impact of oligopsony power on corn prices shifts the seed demand inward, implying lower  $P$ .

### **Linear Simulation Model**

While the general effects of market power on the market impacts due to the ethanol subsidy are important to discern, the likely magnitudes of impact are also important, particularly as they pertain to the distribution of benefits from the subsidy. To quantify these impacts requires analytical solutions for the market equilibrium and, thus, a parameterized model, which requires

positing specific functional forms for processors' derived demand for corn and farm marginal cost of corn production. Define the downstream demand for processed corn products net of the processing sector's unit costs for all inputs except corn as the linear function:

$$(12) \quad F = f - b = \frac{a - Q}{m},$$

or in direct form as  $Q = a - mF$ . Note that under perfect competition (12) would comprise the processing sector's derived demand function for corn and we could set  $F = p$ .

To parameterize farm corn supply, let  $c(q) = 0.5\beta q^2$ . Then  $c'(q) = \beta q$ , and  $p = P + \beta q$  defines the individual farmer supply relationship. Solving for  $q$ , yields  $q = \frac{p - P}{\beta}$ , which defines the direct supply relationship for the representative farmer. Aggregating over  $n$  homogeneous farmers, the industry supply in the corn market is

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

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

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

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

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

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

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

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

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

Finally, we replace the unit-dependent demand slope parameter,  $m$ , with the unit-free demand elasticity,  $\eta$ , evaluated at the competitive equilibrium:

$$\eta = \left| \frac{\partial Q}{\partial F} \frac{F}{Q} \right| = m.$$

Given these preliminaries, the farm supply (seed demand) in the corn (seed) market in the parameterized model can be expressed as

$$(3'') \quad Q = (p - P) / (1 - w),$$

or in inverse forms as  $p = P + Q(1 - w)$  and  $P = p - Q(1 - w)$ . The downstream demand net of per-unit processing costs (in the absence of the subsidy) can be written as

$$Q = 1 + \eta(1 - F),$$

or in inverse form as

$$(13) \quad F = \frac{\eta + 1}{\eta} - \frac{Q}{\eta}.$$

The supply relationship in the corn seed market is defined by the constant marginal cost function:  $MC = w = P$ .

Recasting (7) in the framework of the linear simulation model, yields the following equilibrium condition in the corn market:

$$(14) \quad F + \tau - P = \frac{\eta + 1}{\eta} - \frac{Q}{\eta} + \tau - P = Q(1 - w)[1 + \theta].$$

Similarly, the equilibrium condition (9) in the seed market in the simulation framework is

$$(15) \quad p - w = Q(1 - w)(1 - \xi).^{10}$$

Alternative representations of (14) and (15) that are particularly convenient for graphical exposition involve the use of the concepts of perceived marginal cost (PMC) and perceived marginal revenue (PMR) curves. Following Melnick and Shalit and ASZ, PMC consists of a linear combination of the inverse corn supply function,  $p = S(Q|P) = P + (1 - w)Q$ , and the marginal acquisition cost curve,  $MAC(Q|P) = P + 2(1 - w)Q$ , that a pure monopsonist would face. The weight given to  $MAC(Q|P)$  is the degree of oligopsony power exercised by the industry. The corn market equilibrium condition can then be expressed using the PMC function as

$$(14') \quad PMC(Q|P, \theta) = (1 - \theta)S(Q|P) + \theta MAC(Q|P) = F + \tau = \frac{\eta + 1}{\eta} - \frac{Q}{\eta} + \tau.$$

Similarly, the PMR curve is defined as a linear combination of farmers' inverse demand function for seed,  $P(Q|p, w) = p - Q(1 - w)$ , and the marginal revenue function,  $MR(Q|p, w) = p - 2(1 - w)Q$ , that a pure monopoly seed seller would face, where the weight given to  $MR(Q|p, w)$  is the degree of oligopoly power possessed by seed producers. The seed market equilibrium condition can then be expressed using the PMR function as:

$$(15') \quad PMR(Q|p, w, \xi) = (1 - \xi)P(Q|p, w) + \xi MR(Q|p, w) = w.$$

Figures 1 and 2, respectively, use (14') and (15') to illustrate the model for the cases of oligopsony in corn procurement, and perfect competition in seed sales, and perfect competition

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<sup>10</sup> Given the specification of producer marginal costs in the simulation model,  $\varepsilon = 1$ .

in corn procurement and oligopoly in seed sales. In both cases the market-power equilibrium is presented relative to the competitive equilibrium. The most general case of both oligopoly and oligopsony power 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.<sup>11</sup> The higher corn production also increases the farm price for corn, as farmers move along their supply curve,  $S(Q|w)$ . Although the demand for seed shifts right due to a higher corn price, 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 both oligopsony and perfect competition, but the effects are muted in oligopsony, as 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 (seed manufacturer oligopoly), 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). Although the subsidy-induced expansion in corn output is necessarily greater under perfect competition, the fact that the subsidy induces

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<sup>11</sup> The case with perverse comparative statics (footnote 9) does not occur in the linear model.

an inward shift in corn supply under seed manufacturer oligopoly causes the relative magnitudes of  $p_C^1 - p_C^0$  and  $p_O^1 - p_O^0$  to be indeterminate, as discussed in the general model comparative static analysis.

Equilibrium in the simulation model is described by equations (3''), (13), (14') and (15'), which represents a system of four equations that can be solved simultaneously to yield equilibrium values for the four endogenous variables,  $Q$ ,  $p$ ,  $P$  and  $F$ :

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

$$F^* = \frac{\eta + 1}{\eta} - \frac{Q^*}{\eta}$$

$$P^* = w + \xi Q^* (1 - w)$$

$$p^* = P^* + Q^* (1 - w).$$

## Simulation Results

To conduct the simulations, we must specify ranges of values for the model's five parameters: the market power parameters,  $\xi$  and  $\theta$ , the price elasticity of farm-level demand for corn,  $\eta$ , 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,  $\tau$ . Values for  $\eta$ ,  $w$ , and  $\tau$  were chosen to approximate conditions in the U.S. corn market, and, given the focus of the paper, a wide range of values for  $\xi$  and  $\theta$  were considered.

For the base simulation  $\eta = 0.727$  was chosen based upon the estimate by Shonkwiler and Maddala.<sup>12</sup> The corn seed cost share was set at  $w = 0.12$  (Foreman). The elasticity of derived demand for seed at the competitive equilibrium is thus

$$\left| \left( \frac{\partial Q}{\partial P} \right) \left( \frac{P}{Q} \right) \right| = (1 / (1 - w))(0.12) = 0.136.$$

A number of steps were 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,  $\$0.2856/2.2572 = \$0.1265 = \tau$ , yields the appropriate value of the all-corn equivalent of the ethanol subsidy for the simulation model.

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<sup>12</sup> This estimate is somewhat more elastic than the value of  $\hat{\eta} = 0.346$  obtained subsequently by Holt and Johnson. The Holt and Johnson estimate is close to the estimate of 0.30 used by the U.S. Department of Agriculture, Economic Research Service (Jefferson-Moore and Traxler). These estimates were obtained prior to ethanol becoming an important use for corn, and arguably this component of demand is quite elastic, given given the intent of the subsidy to make ethanol competitive as a motor fuel. Thus, our choice was to use the more elastic of the published alternatives. We also test the sensitivity of results to variations in the price elasticity of corn demand (figure 10).

The simulation results are summarized in figures 3-10 and in table 1. 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. For expository purposes we depict the entire range of possible market power values from zero to one. 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 when both upstream and downstream market power are considered is purely for expository purposes. Table 1 gives results for positive but unequal values for  $\xi$  and  $\theta$ .

The impacts of the ethanol subsidy on the farm price of corn,  $p$ , the gross farm margin,  $p - P$ , and downstream composite product price net of per-unit processing costs,  $F$ , and production of corn (and seed),  $Q$  are reported in figures 3, 4, and 5, respectively. In each case, the impact of the subsidy is reported as a percent of the impact achieved under perfect competition.<sup>13</sup> Consider the change in corn output first (figure 5). Given the goal of the ethanol subsidy to expand ethanol production and reduce U.S. reliance on imports of fossil fuels, it is noteworthy that 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  $\xi$  or  $\theta$  equal to 0.3, the change in production is just over 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. The lower rate of output expansion under market power is a direct consequence of firms with market power recognizing the impacts of their actions on the prices they pay (processor oligopsonists) or

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<sup>13</sup> These percent impacts for  $F$  and  $Q$  are identical in the simulation model, enabling both to be presented in figure 5.

receive (seed manufacturer oligopolists) and accordingly purchasing and selling less than price-taking firms.

Downstream consumers of corn products and corn farmers always receive a price off of their demand and supply curves, respectively. Thus, the contraction of the output expansion from the subsidy caused by processor oligopsony power insures that the downstream composite price will decrease less (figure 5) and the farm price will increase less (figure 3) due to the subsidy under processor oligopsony power than under perfect competition. The effects for moderate levels of oligopsony power are quite modest, however. For example, for  $\theta = 0.3$ , the increase in farm price is 89.5 percent of the increase attained under perfect competition, and the decrease in the composite-product price is 92.8 percent of the decrease attained under perfect competition.

The impact on the market of oligopoly power exercised by seed producers is somewhat more complicated and is substantial, even though the seed share of the total corn product is not high, because the demand for seed is very price inelastic.<sup>14</sup> Given inelastic demand, seed prices increase rapidly as a function of seed producers' oligopoly power, causing the farm supply of corn to shift back (e.g., see figure 2). The positive effect on  $p$  of this inward shift in the corn supply more than offsets the negative impact on  $p$  caused by a reduced rate of output expansion from oligopoly power, and farm price for corn increases on net. For example, the increase in the farm corn price due to the subsidy is 16 percent larger when seed producers exercise modest oligopoly power,  $\xi = 0.3$ , than when they sell seed competitively (figure 3). 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

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<sup>14</sup> The inelasticity of input demand for seed is consistent with 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), both of which are true in this model.

illustrates, equivalent degrees of oligopoly and oligopsony power have the same impact on the change in the gross farm margin in this model.<sup>15</sup>

When equivalent degrees of oligopoly and oligopsony power are exercised simultaneously, the change in the farm price due to imposition of the subsidy is positive and is increasing, albeit slightly (figure 3), as a function of the degree of market power exercised, but the increase in the gross farm margin,  $p - P$ , from the subsidy (figure 4) is decreasing as a function of market power because the increase in the seed price dominates the small increase in the corn price. For example, for  $\xi = \theta = 0.3$  the increase in  $p - P$  due to the subsidy is only about 81 percent of what is achieved under perfect competition.

These results on prices and outputs are consistent with prior observations 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 hold rather generally.

Next we consider the impacts of market power on the distribution of benefits from the subsidy among farmers, corn processors, and seed producers. Figures 6, 7, and 8, respectively, indicate the change in the share of profits earned by farmers, corn processors, seed producers, and downstream consumers as a function of the degree of seed producer oligopoly power, corn

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<sup>15</sup> This result holds the linear model (but not generally) because two factors fully offset. First, oligopsony power is more important than oligopoly power in this model because oligopoly power matters only in proportion to seed's importance as an input in producing corn. Offsetting this consideration is that oligopoly power distortions are magnified relative to oligopsony power distortions because seed demand is inelastic, based upon its input share, relative to farm supply.

processor oligopsony power, and combined seed producer and processor market power, respectively.

The distributional effects of market power are generally much larger than the impacts on prices and output. In the base simulation because downstream demand for processed corn products is less price elastic than corn supply, downstream users capture about 60 percent of the subsidy benefits, while farmers capture the other 40 percent under perfect competition. Competitive seed producers and corn processors capture none, due to the assumption that they operate with constant returns technologies. For reasons explained earlier (see footnote 15), the distributional impacts on downstream consumers and farmers in this model are identical for equivalent magnitudes of seed manufacturer oligopoly power (figure 6) or processor oligopsony power (figure 7).<sup>16</sup> The benefits attained by both farmers and downstream consumers decline monotonically as a function of either oligopoly or oligopsony power. Seed producers (corn processors) are able to capture significant benefits from the subsidy when they have oligopoly (oligopsony) power. For example, when  $\xi = 0.3$  ( $\theta = 0.3$ ), seed manufacturers (corn processors) capture about 19 percent of the subsidy benefits. When  $\xi = 0.5$  ( $\theta = 0.5$ ), the equivalent of a symmetric Cournot duopoly (duopsony), seed manufacturers (corn processors) capture a roughly equivalent benefit share to farmers—about 27 percent each.

When market power is exercised both upstream and downstream from the farm (figure 8, table 1), the share of benefits from the subsidy attained by both farmers and downstream consumers declines as a function of the magnitude of market power exercised at a more rapid rate than when market power is exercised in only one sector. For example when  $\theta$  or  $\xi$  equals 0.3, farmers capture 31.3 percent of the subsidy benefit, while downstream consumers receive

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<sup>16</sup> Figures 6 and 7 are not identical because of differences in the deadweight loss between processor oligopsony power and seed manufacturer oligopoly power. The deadweight loss for equivalent magnitudes of market power is

48.9 percent. When  $\theta = \xi = 0.3$ , farmers' share is reduced to 25.6 percent and consumers' share is reduced to 40.0 percent.

Oligopoly power exercised by seed manufacturers is harmful to oligopsony processors and vice versa. Oligopsony power enables processors to reduce the price paid to farmers for corn below the competitive level, but farmers' input costs are higher when seed producers exercise oligopoly power. This causes the farm supply curve to shift back (figure 2), harming processors when they have market power because they rationally absorb part of farmers' higher input costs through paying a higher price for corn. Thus, while processors capture 19 percent of the subsidy benefits when  $\theta = 0.3$  and  $\xi = 0$ , they capture only 15.9 percent when  $\theta = \xi = 0.3$ .

Similarly, processor oligopsony power depresses the price for corn, which reduces the upstream demand for seed. Whereas this has no effect on competitive seed manufacturers in this model, it harms oligopoly seed manufacturers because they rationally absorb a portion of the lower farm corn price by reducing the price for seed. Thus, while seed manufacturers capture 18.8 percent of the subsidy benefits when  $\xi = 0.3$  and  $\theta = 0$ , their share is only 15.4 percent when  $\theta = \xi = 0.3$ .

Figure 9 demonstrates, however, that total revenue in the presence of the subsidy from downstream sales of corn products net of processor costs, i.e.,  $F \cdot Q$ , is actually increasing in the extent of market power for a range of values of  $\theta$  and/or  $\xi$  even though there is no market power exercised over downstream consumers in this model. The reason is that downstream demand is inelastic in the base model, so the industry is operating in the declining portion of the total revenue function. Market power acts as a form of commitment device, reducing downstream sales, to enable the industry to move closer to the revenue-maximizing amount of corn

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less for seed manufacturer oligopoly power because seed demand is more inelastic than farm supply. See table 1 for specific examples.

production. For higher levels of market power, especially when seed manufacturers and processors each exercise market power, total revenue declines in the degree of market power exercised because total sales are in the elastic range of downstream demand.

### *Sensitivity Analysis*

Given that the preceding analysis simulates all feasible values for the market power parameters,  $\xi$  and  $\theta$ , the remaining parameter of interest for purposes of sensitivity analysis is  $\eta$ , the absolute elasticity of farm-level demand for corn, evaluated at the competitive equilibrium. The estimate of  $\eta = 0.727$  in the base simulation is high relative to other estimates (see footnote 12). However, these estimates were all based on data prior to the advent of markets for corn ethanol and the growth of markets for various corn-based food additives. In some of these cases good substitutes exist for the corn-based product, e.g., gasoline for ethanol and sugar for high fructose corn syrup, which may make corn demand more elastic than the econometric estimates suggest. Thus, our strategy was to evaluate the sensitivity of simulation results to both more elastic,  $\eta = 1.0$ , and less elastic,  $\eta = 0.3$ , corn demand.

Figure 10 depicts how the farmers' share of the benefit of the subsidy changes in the presence of increasing levels of seed producer oligopoly power and corn processor oligopsony power for the three different demand elasticities. If downstream demand for corn products is very inelastic relative to farm supply, downstream entities capture most of the subsidy benefits even under perfect competition. In this sense, although market power decreases the farm share, the importance of market power in determining the distribution of subsidy benefits is diminished. When the demand elasticity is higher, such as  $\eta = 1$ , the farm share under perfect competition is, of course, larger, but it diminishes faster as a function of upstream and downstream market

power. Thus, market power is a more important factor in determining the amount of subsidy benefits captured by farmers the more elastic is downstream demand relative to farm supply.

## **Conclusion**

Market power is mentioned frequently in debates regarding impacts of subsidies for ethanol production, and structural conditions in the industry create a prima-facie case for concerns about its presence. However, analyses to date of the subsidy's impacts have assumed competitive markets. The purpose of this paper was to construct and analyze 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. Analytical results from the general model demonstrated that market power, whether exercised by oligopsony corn processors or oligopoly seed manufacturers, would attenuate the expansion in corn output due to the subsidy, which, accordingly, would reduce the net price reduction received by downstream users of processed corn products. Oligopsony power unambiguously causes a smaller increase in the farm price due to the subsidy. Seed manufacturer oligopoly power has an ambiguous effect on the corn price due to offsetting effects.

For reasonable parameterizations of the corn sector, the results from a linear simulation model demonstrated that the impacts on prices and output were modest for small 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, large multinational corporations in each case, capture relatively large shares of the benefits from the subsidy when they have market power is relevant to the policy debate. In the base simulation farmers' share of the total subsidy benefit was only about 25 percent when

relatively moderate levels of market power ( $\theta = \xi = 0.3$ ) were exercised by both processors and seed manufacturers.

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, concentration among seed manufacturers is relatively high, and genetically modified seeds with patented traits also can enhance market power in seed sales.

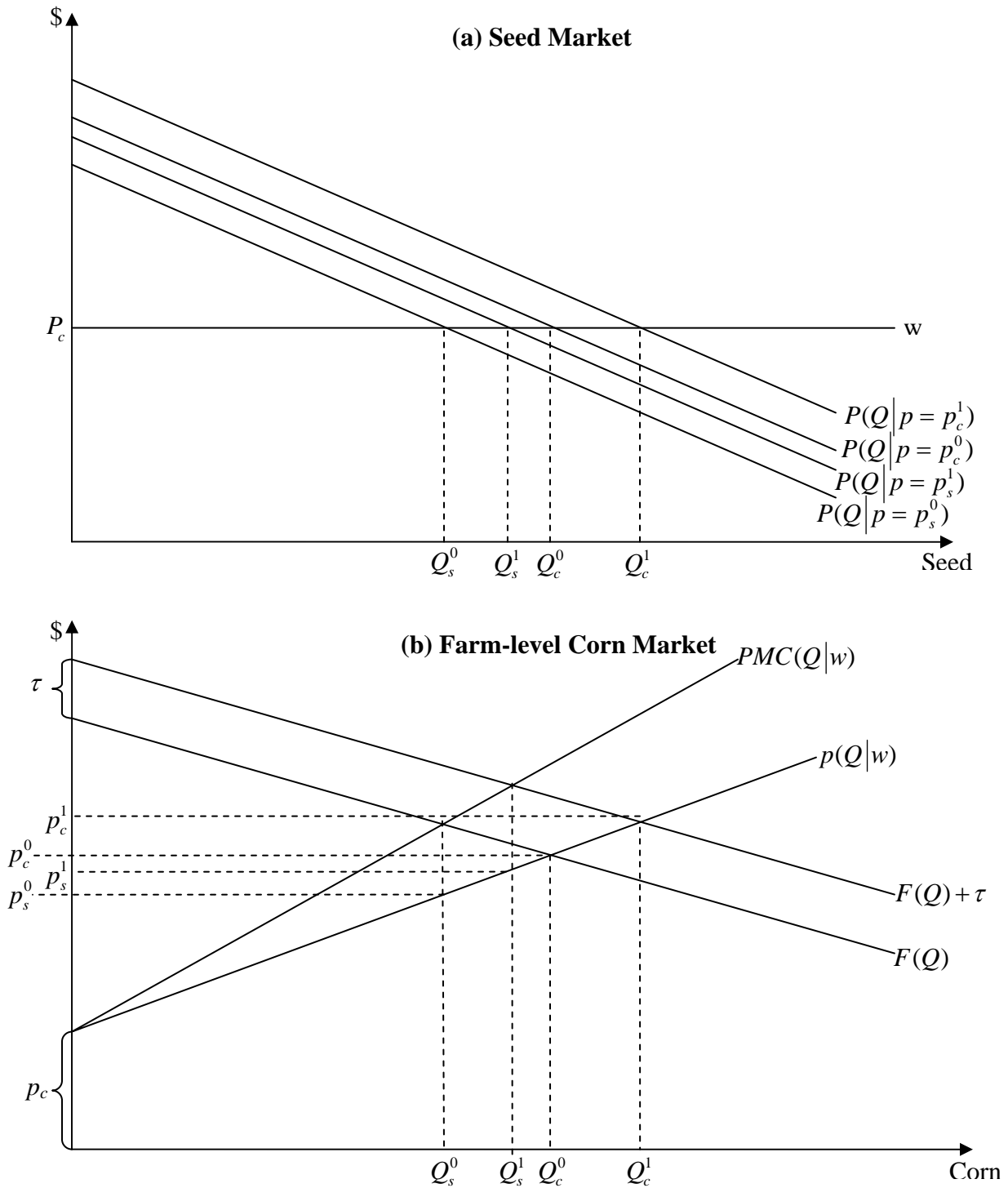
Elasticities of the relevant functions play a key role in influencing the distribution of benefits from the ethanol subsidy under perfect competition based upon the usual incidence analysis. Their effect is magnified in the presence of market power because the distorting impact of market power depends upon the elasticity of the underlying supply or demand function that is being exploited. The relative inelasticity of seed demand 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. An interesting aspect of market power in the presence of inelastic downstream demand is that it acts as a commitment device for the industry to credibly reduce output and achieve higher revenues from the sale downstream of corn products.

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 regarding corn and seed production and that corn products are sold competitively downstream.

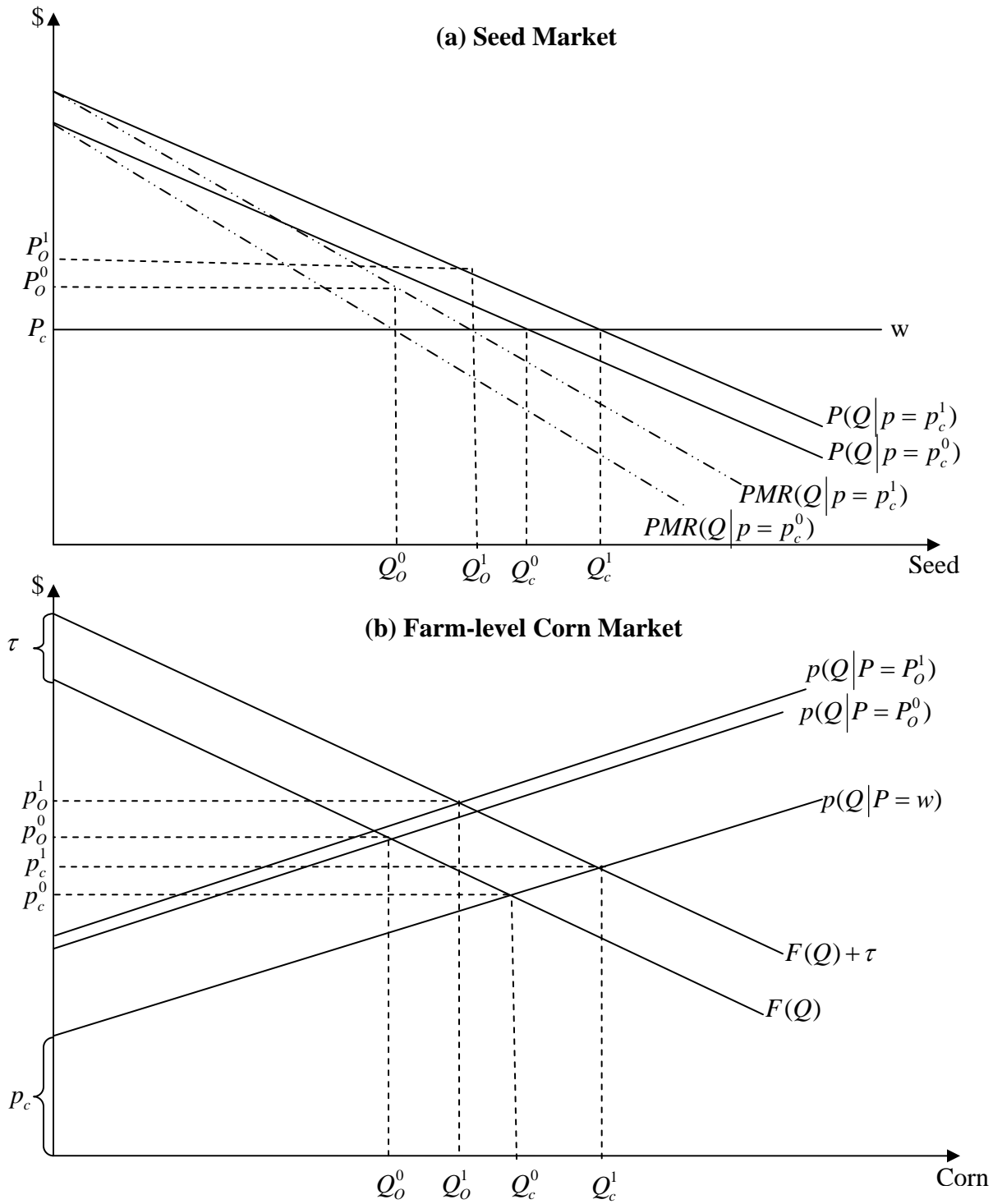
**Table 1. Percentage Distribution of Benefits from the Ethanol Subsidy for Alternative Levels of Processor Oligopsony and Seed Manufacturer Oligopoly Power.**

		Processor Oligopsony Power							
		$\theta = 0.0$		$\theta = 0.1$		$\theta = 0.3$		$\theta = 0.5$	
Seed Manufacturer Oligopoly Power	$\xi = 0.0$	Seed mfg.	0.0	Seed mfg.	0.0	Seed mfg.	0.0	Seed mfg.	0.0
		Farmer	39.0	Farmer	36.1	Farmer	31.3	Farmer	27.3
		Processing	0.0	Processing	7.2	Processing	19.0	Processing	28.1
		Downstream	61.0	Downstream	56.5	Downstream	48.9	Downstream	42.7
		DWL	0.0	DWL	0.1	DWL	0.9	DWL	1.9
	$\xi = 0.1$	Seed mfg.	7.2	Seed mfg.	6.7	Seed mfg.	5.8	Seed mfg.	5.1
		Farmer	36.1	Farmer	33.6	Farmer	29.2	Farmer	25.6
		Processing	0.0	Processing	6.7	Processing	17.8	Processing	26.6
		Downstream	56.5	Downstream	52.5	Downstream	45.6	Downstream	40.0
		DWL	0.1	DWL	0.5	DWL	1.5	DWL	2.6
	$\xi = 0.3$	Seed mfg.	18.8	Seed mfg.	17.5	Seed mfg.	15.4	Seed mfg.	13.6
		Farmer	31.3	Farmer	29.2	Farmer	25.6	Farmer	22.7
		Processing	0.0	Processing	5.9	Processing	15.9	Processing	24.0
		Downstream	48.9	Downstream	45.6	Downstream	40.0	Downstream	35.4
		DWL	1.1	DWL	1.7	DWL	3.0	DWL	4.3
	$\xi = 0.5$	Seed mfg.	27.3	Seed mfg.	25.6	Seed mfg.	22.7	Seed mfg.	20.2
		Farmer	27.3	Farmer	25.6	Farmer	22.7	Farmer	20.2
		Processing	0.0	Processing	5.3	Processing	14.4	Processing	21.9
		Downstream	42.7	Downstream	40.0	Downstream	35.4	Downstream	31.6
		DWL	2.7	DWL	3.4	DWL	4.8	DWL	6.2

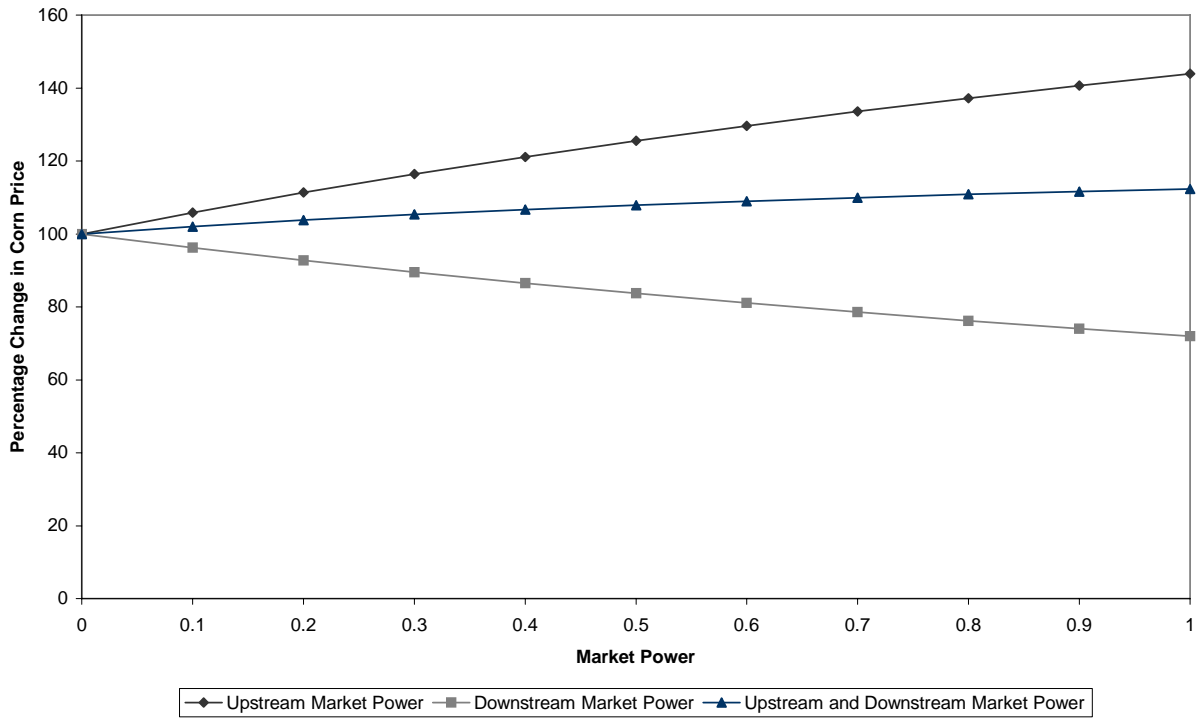
**Figure 1. Impact of the Ethanol Subsidy when Corn Processors Have Oligopsony Power.**



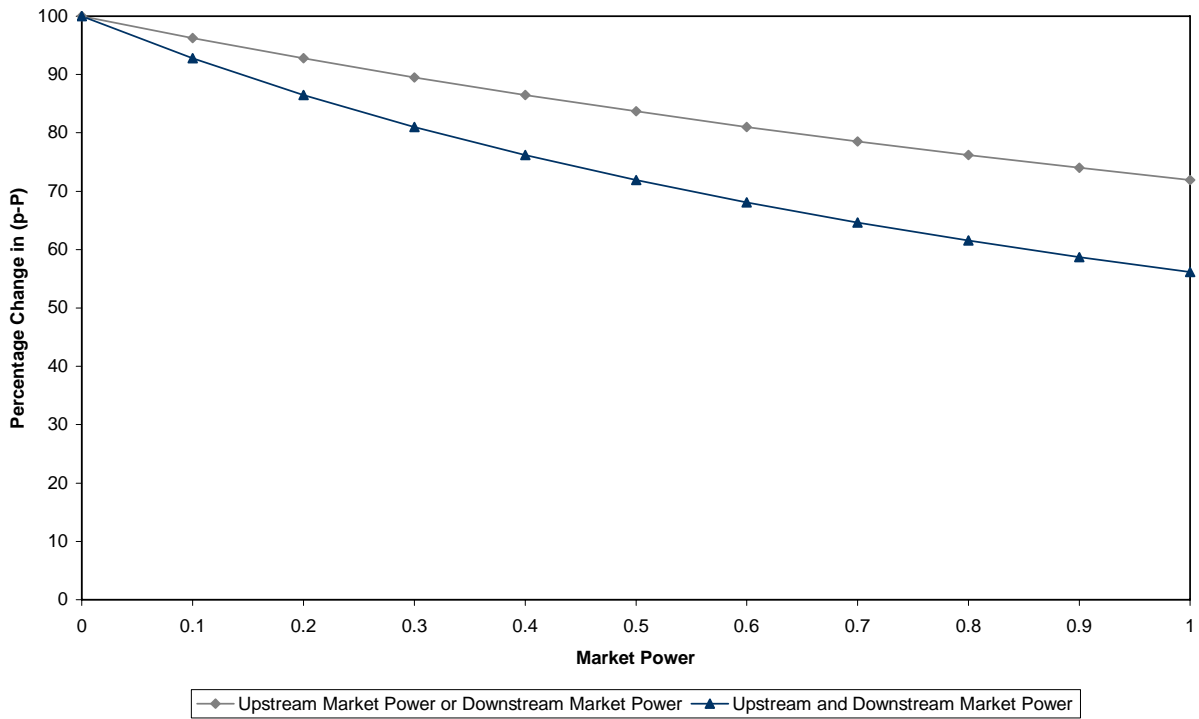
**Figure 2. Impact of the Ethanol Subsidy when Seed Manufacturers have Oligopoly Power.**



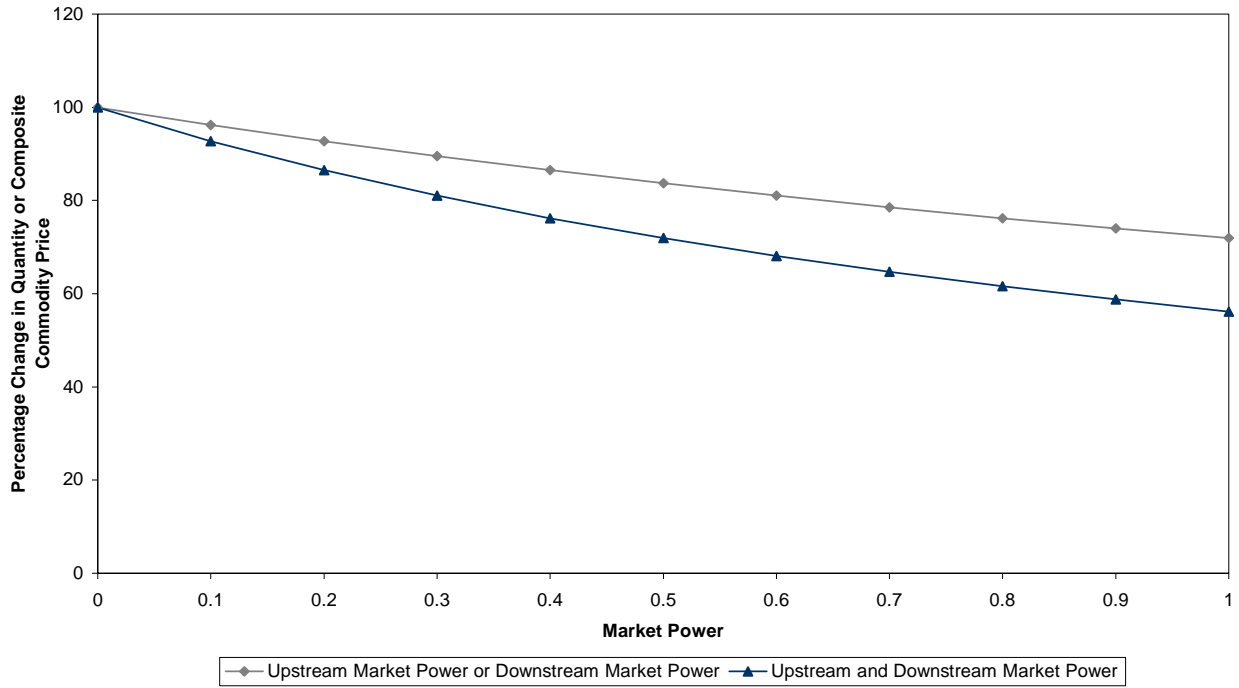
**Figure 3. Impact of the Subsidy on the Price of Corn Under Market Power: Percentage Change Relative to Perfect Competition.**



**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 and Price of the Composite Processed Commodity Under Market Power: Percentage Change Relative to Perfect Competition.**



**Figure 6. Distribution of the Subsidy Benefit Under Seed Producer Oligopoly Power.**

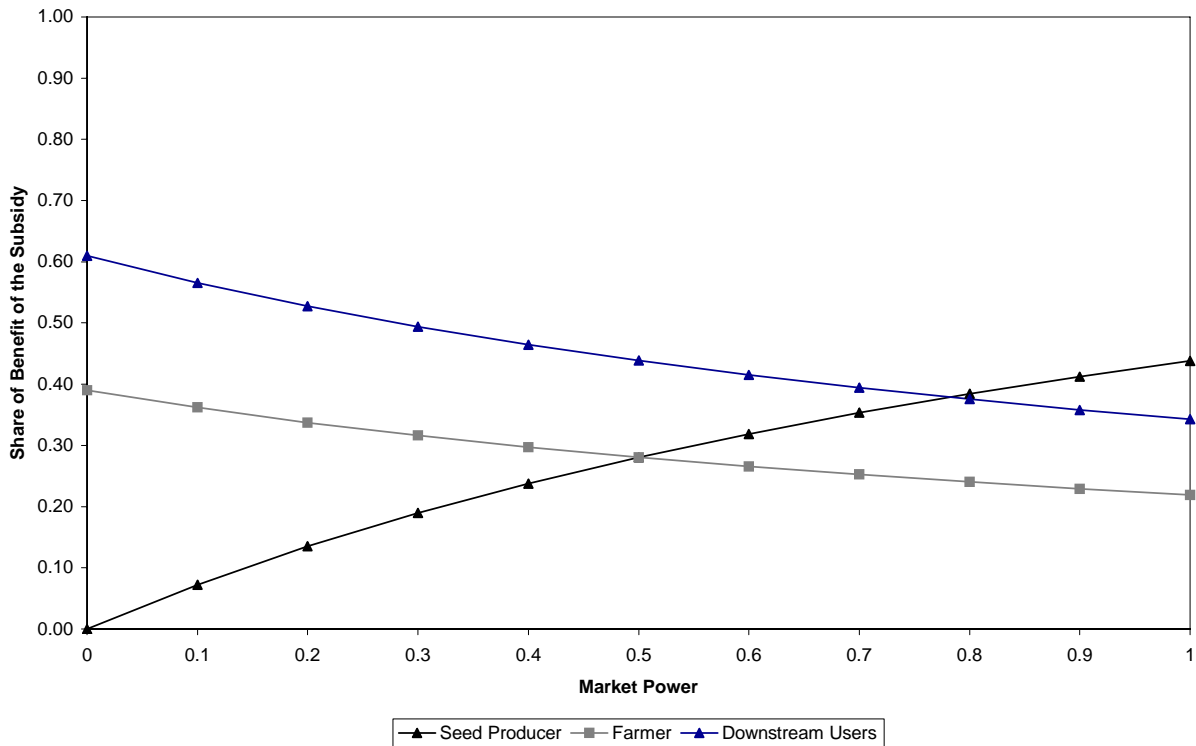


Figure 7. Distribution of the Subsidy Benefit Under Corn Processor Oligopsony Power.

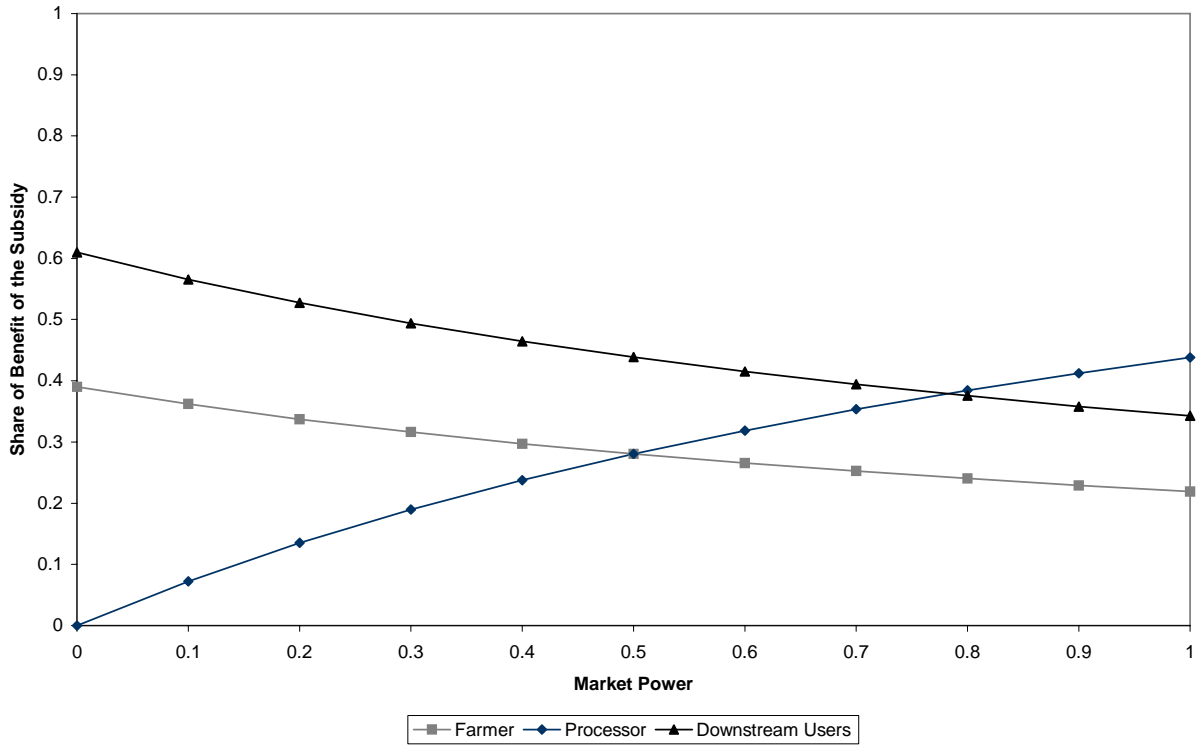
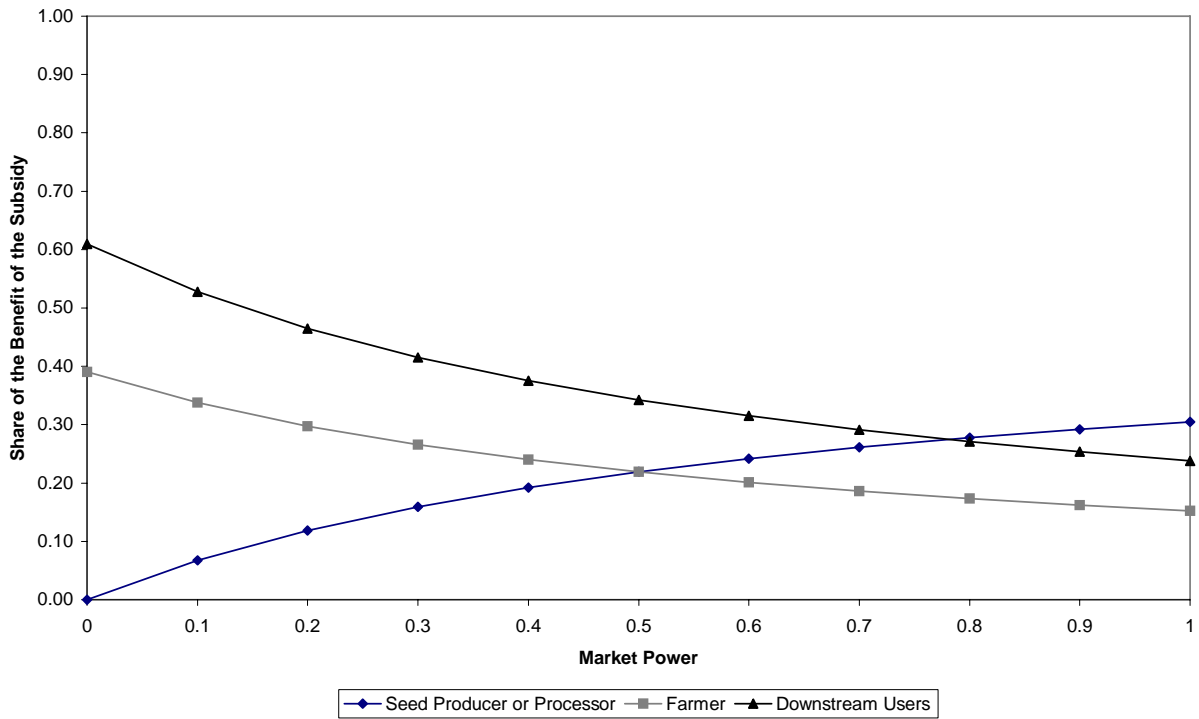
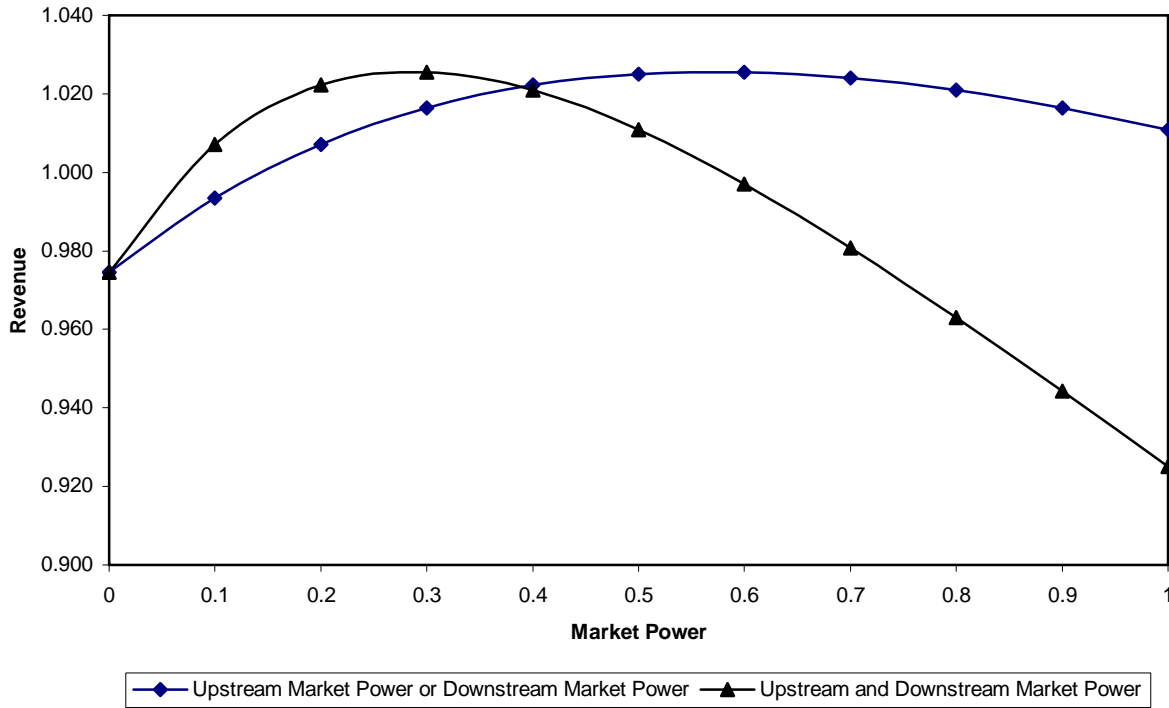


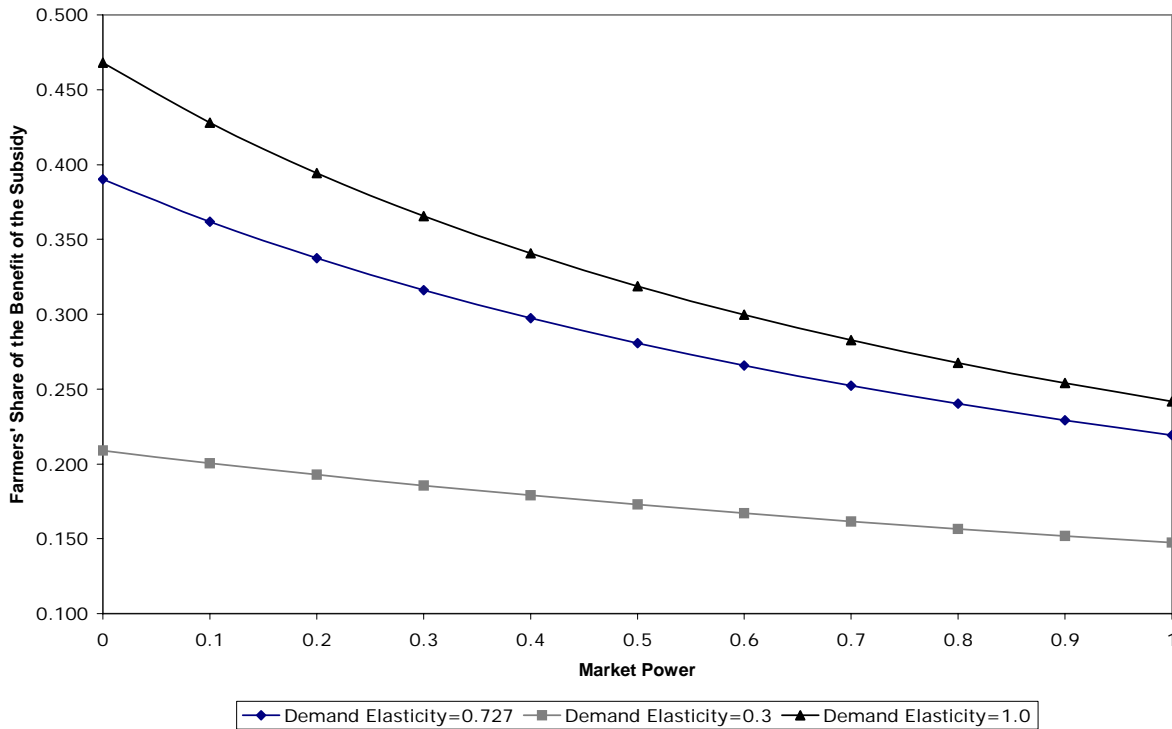
Figure 8. Distribution of the Subsidy Benefit Under Seed Producer Oligopoly Power and Corn Processor Oligopsony Power.



**Figure 9. Revenue From the Sale of Corn Products Under Seed Producer Oligopoly Power and Corn Processor Oligopsony Power.**



**Figure 10. Farmers' Share of the Total Subsidy Benefits in the Presence of Seed Producer Oligopoly Power and Corn Processor Oligopsony 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):

$$\begin{aligned} p_1 &= a_1 + b_1 Q_1 + \tau_1 \\ p_2 &= a_2 + b_2 Q_2 \end{aligned} ,$$

where corn used for ethanol receives a per-unit subsidy of  $\tau_1$ . Writing the demands in their direct form, setting  $p_1 = p_2$  based upon the product-form arbitrage condition, and summing yields the following aggregate demand function:

$$Q = \frac{b_1 + b_2}{b_1 b_2} P - \frac{b_1 a_2 + b_2 a_1}{b_1 b_2} - \frac{b_2}{b_1 b_2} \tau_1.$$

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

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

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:

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

For the subsidies to be equivalent, we need  $(b_1 + b_2)\tau = b_2 \tau_1 \rightarrow \tau = \tau_1 b_2 / (b_1 + b_2)$ , where

$$\frac{b_2}{b_1 + b_2} = \frac{Q_1(p - a_2)}{Q_2(p - a_1 - \tau_1) + Q_1(p - a_2)}.$$

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  $a_1 + \tau_1 \approx a_2$ , 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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