

## **SOME PRICE AND COST ANALYSIS FOR THE CORN PROCESSING SECTOR**

Paul Gallagher  
Associate Professor  
Department of Economics

Guenter Schamel  
Assistant Professor  
Humboldt University (Berlin)

Hosein Shapouri  
U.S. Dept. of Agriculture

Corn processors use only the starch component of the corn plant. Some processors sell starch for paper coating or food extender. Others process further to sell glucose or fructose sugar in the sweetener market. Increasingly, processors convert the sugars to alcohol for sale as a fuel additive. But the byproduct components of the corn plant have market value as animal feed and vegetable oil for human consumption. Indeed, corn processors typically recover about one-half of the corn input cost through byproduct sales. The net corn cost in figure 1 represents the cost of the starch input to the corn processor.

Hence, impending expansions in the corn processing industry have several consequences that affect the corn processing sector. For instance, an expansion of corn processing causes rising corn prices. But increasing byproduct supplies may also reduce byproduct feed prices. Combined corn and byproduct adjustments mitigate the adverse cost movement for feed consumers but could produce narrower processing margins.

This report investigates and measures the effects of changing levels of corn processing on agricultural prices and processing costs. First, the nature of input and byproduct markets in the corn processing sector are summarized. Second, price relationships between major agricultural commodities and the products of the corn processing industry are analyzed for an assessment of competition. Third, measurements of the effect of supply changes on product prices are given. Specifically, a hypothetical doubling of corn processing would have a moderate effect on net corn costs because the corn price increases and byproduct price reductions are both moderate.

### **Processes, Byproducts and Markets**

The byproducts of corn processing generally have a value per ton that is substantial in the composite corn value because each byproduct has attributes that are useful in a feed or food. Corn processors choose between a wet-mill and a dry-mill when they construct their plant. The advantage of a wet-mill is that the byproducts can be separated into components. Specifically, the byproducts of wet-milling are corn gluten feed (GF) with 21% protein, corn gluten meal (CGM)



with 60% protein, and corn oil (CO) with desirable taste and low saturated fat. Those who choose a dry mill do not separate the byproduct into components. Instead, they sell one composite byproduct, distillers dried grain (DDG), that more or less includes all three wet mill by products.

It is true that the byproduct revenues from wetmills exceed the byproduct revenues from a dry mill, when expressed on a \$/gallon of ethanol processed basis (figure 1a), while the ethanol yield and revenues are about the same. Further, the incremental investment for the separation equipment in a wet mill amounts to \$.30/gallon in a very large 100 million gallon plant—this comes to an annual capital cost of \$.04/gallon in a large plant with a 15 year plant life and a capital cost of 10%. Consequently, the revenues justify the additional capital investment in a large plant.

The rub is that the capital cost-size relationship favors much smaller dry mill ethanol plants, say in the neighborhood of 40 or 50 million gallons. Then the same investment in wet-milling conversion must be spread over less than half the output. For instance, \$.60/gal investment to produce the higher-valued wet-mill products converts to a \$.08/gal capital cost. Then the incremental investment is not justified. The particulars of plant location decisions sometimes favor dry mills and sometimes favor wet mills. So both byproducts will continue to be produced. All of the byproducts find local and international markets.

First, corn gluten feed can replace corn and some more expensive soy meal in a dairy cow ration (Weigell, et al., 1997b). So corn gluten feed is sometimes a cost reducing strategy in a dairy ration. Local dairy farms and dairy replacement operations near corn processing facilities account for much of the consumption of gluten feed. But 40% of U.S. gluten feed was exported in the 2001 crop year, mostly to European dairy and hog industry for similar reasons.

Corn gluten meal has a considerable foreign market. 36% of production was exported in 2001. Most of these exports go to Asia.

Distillers' grains may be best suited to a poultry ration because the energy, protein and fat components are all needed. Further, distillers' grains have a relatively high concentration of methionine ( Weigell, et al 1997a). Methionine is often a deficit attribute in a poultry ration. Because poultry rations, need all four components one would eventually expect the dominant use in the poultry industry. In 2001, 32% of DDG production was exported. Most of these exports to the same European countries that buy gluten feed.

Finally, corn oil is considered a high-quality vegetable with low saturated fat, and many favor its taste characteristics. About 30% of corn oil is exported

### **Some Observations about Price Relationships**

Corn processing byproducts can substitute easily for similar feeds and foods. Further, an examination of the price ratio between a byproduct and a potential substitute provides some evidence of the extent of competition—price ratios should be expressed per unit of a desirable



attribute. If the price ratio exceeds unity, then because the attributes are valued equally in the marketplace, feeders would shift to substitutes, bid the price of the substitute up and reduce the price ratio towards unity. This arbitrage process tends to restore price parity between close substitutes. In contrast, a price ratio above unity can persist when the byproduct has other unmeasured attributes that are valued in the marketplace. Finally, the price ratio comparison would appear random when there is no economic relationship between the comparison commodities.

First, let's examine the price ratio for gluten feed relative to corn, when the prices for both commodities are expressed on a dollars per total digestible nutrient (TDN) basis. This chart suggests that CGF priced above its nutrient content value of over most of the last 20 years. However, during the last five years, CGF prices are on a parity with the TDN content of corn. This price ratio suggests a close substitution between corn and CGF.

Second, let's examine the price ratio for gluten meal relative to soymeal, when the prices for both commodities are expressed on a dollars per pound of protein basis. This chart suggests that CGM priced above its protein content value of over most of the last 20 years. However, CGM prices occasionally drop down to parity with the protein content of soybean meal. Again, this price ratio suggests a close substitution between soy meal and CGM.

Third, let's examine the price ratio for corn oil relative to soybean oil when the prices for both commodities are expressed on a dollars per pound basis. CO has consistently priced above SO over the last 20 years, perhaps due to preferred taste and fat quality advantage. However, the CO premium has declined during the last 5 years.

There are also some reasons to expect a close economic relation between DDG and the component prices of wet-mill byproducts. Specifically, poultry feeders require a high protein diet that usually adds some fat. Further, CGM also contains methionine, an amino acid that is often scarce in poultry rations. Thus, DDG prices at a moderate premium to CGF; this may occur because poultry feeders are willing to pay for the protein fat and methionine, but will substitute for other sources when the CGM price significantly exceeds the base protein price.

### **Price Response Estimation**

We measure the extent of price adjustment to a change in the supply on the corn, CGF, CGM, and CO using a conventional price flexibility approach, which measures the effects of changing commodity supply price while accounting for commodity substitution (Tomek, p.309). The method is suited to corn and byproduct markets because the lines of causation probably run from supplies available on the market to prices, due to external weather or policy change.

To illustrate the nature of price adjustment to a supply change when products are demand substitutes, consider figure 3. The supply for good 1 and good 2 are both vertical lines, given the assumption that their levels are given by events that occur outside the market. If there is a reduction in supply of good 2 (to  $Q_2^1$ ), then the price of good 2 rises (to  $P_2^1$ ). As a consequence,



the demand curve for good 1 shifts out ( to  $D(P_1; P_2^1)$  ), and the price increases (to  $P_1^1$  ). A reduction in supply of good 1 (to  $Q_1^1$  ), while not shown, would also cause an increase in the price of good 1, by a movement along the demand curve.

Hence, price response can be estimated by regressions which explain the historical variation in price with the commodity's supply and the supply of substitutes as the appropriate explanatory variables. Attention to the particulars of the corn and byproduct markets is also required for an appropriate specification.

First, the previous inspection of relative prices suggested that corn byproducts tend to price at a slight premium or parity with a dominant agricultural commodity with similar qualities. Specifically, CGF substitutes closely for corn, CGM substitutes closely with soy meal, and CO substitutes closely with soy oil. Our explicit consideration of substitutes is limited to these specific instances.

Measurement of the effect of substitute price changes on the demand for an individual feed is one of the most difficult problems of applied price analysis, because the prices of these close substitute products are highly co-linear. Some have imposed several mathematical and economic assumptions for estimation of substitution effects (McKensie, Huerta and Paarlberg; Moschini). Other approaches are useful when supply and demand adjust for substitute markets in the short run (Thurman and Wohlgenant). But the flexibility approach is most useful when weather and policy events dominate supply adjustment in the short run. The substitution effects measured by our dominant commodity approach may magnify the substitution effect, to the extent that other substitute prices are moving closely with the price for the dominant commodity.

Second, a demand shifter is also an appropriate explanatory variable, such as animal population or consumer income, since the products are close substitutes and share a common set of growth-inducing variables. The USDA's index of grain consuming animal units is an appropriate demand shifter for the corn, feed, and meal market. Consumer income is an appropriate variable for the corn oil market.

Third, a 'net supply' variable is constructed for each market that approximates the domestic demand. For demonstration, consider the market balance between supply ( beginning inventory  $I_{t-1}$ ; and production,  $Q_t$  ) and utilization (domestic demand,  $D_t$ ; exports  $X_t$ ; and ending inventory,  $I_t$  ):

$$I_{t-1} + Q_t = D_t + X_t + I_t$$

Rearranging gives the domestic demand in terms of production, exports and stocks:

$$NS_t = D_t = Q_t - X_t - (I_t - I_{t-1}).$$

So inventory accumulations and exports are removed from production to arrive at domestic demand, or net supply, when data is available. The net supply variable in the subsequent section is actually an estimation of domestic demand for the commodity that is inferred from other data.



As a first approximation, net supply is exogenous to the market because production and export outcomes are dominated by world weather and policy events. It is this simple fact that makes price response estimation convenient and effective in the corn products sector.

To summarize, a typical linear regression for good 1 has three explanatory variables: the net supply of good 1, the net supply of good 2, and consumer income:  $P_{1t} = a - b NS_{1t} - c NS_{2t} + d Y_t$

## **Results**

Price flexibility estimations were conducted for three commodities: corn, CGF, CGM, and CO. Each price equation includes three variables: the net supply for the commodity, the net supply for a dominant commodity substitute, and a demand shift variable. For the animal feed commodities, the USDA's grain consuming animal units index was used as the appropriate demand shifter. Since corn oil is a food commodity, an income related variable, real personal consumption expenditures, was used as the demand shifter.

The results in table 1a confirm the usefulness of price flexibility estimation because straightforward application of the estimation procedure gave sensible results for all commodities; coefficient signs are consistent with the theory; t-values (in parentheses) generally suggest statistical significance or a contribution to the explanation of historical variation. Finally, the proportion of explained variation is high, especially considering that the estimations explain the behavior of highly variable prices.

Table 1b contains the results for DDG. The historical variation in DDG price is explained well with the price of CGF, CGM, and CO as explanatory variables. The reason is that DDG is a composite commodity and the independent variables are the value of components. This result suggests the DDG will be priced from the prices for wet mill products. DDG usually has a premium over gluten feed, according to these results, because users such as poultry producers are willing to pay for the nutrient, protein and oil content.

## **Accounting for the Interaction of Supply and Demand**

Our estimates have measured the extent to which consumers will bid the price up when the supply for the marketing year falls. This is a short-run response in the sense that the supply for the marketing year is given. But sometimes it is also important to include longer run measures that include producers' response to a price increase.

Take the example of an exogenous expansion in corn processing demand, given by  $D_e$  in figure 4a. Supplies for the marketing year are given at  $Q_c^0$ , so the price is bid up to  $P_c^s$  for the marketing year. However, the market will clear at price  $P_c^e$  if the demand expansion is sustained. Producers' increased supplies partly offset the initial price increase.

By varying the level of the external demand shift,  $D_e$ , in figure 4a, one can construct the excess supply of corn to the processing industry. The excess supply curve is defined as the difference between supply and (feed) demand at a given price. Excess supply curves may be highly elastic, even when production and demand are inelastic (Tweeten); both production and feed demand adjust; and processing volumes are small compared to the size of the overall corn market.

A small simulation model that includes producers' supply response with the price equation estimates is a convenient way of taking the market interactions into account. A summary of this model is given below. Equations 1,2,4 5, and 6 are the estimated price equations. A corn supply function (equation 3) is also included. Corn supply response elasticities are given elsewhere (Gallagher); a production elasticity of 0.6 from acreage and yield components is used in the simulations. Next, equation 7 explicitly states that the corn market clears. Implicitly, equations 2,3 4, and 5 also assume that the market clears, because the net supply variable is substituted for consumption. Finally, The byproduct supply variables include the initial quantity plus a component associated with the exogenous expansion in corn processing( $D_e$ ).  $Y$  refers to a processing yield, and all Greek symbols represent parameters.

1.  $P_c = \alpha_c - \beta_c D_c + \delta_{gf} AU$
  2.  $P_{gf} = \alpha_{gf} - \beta_{gf} (NS_{gf} + Y_{gf} D_e) - \gamma_{gf} D_c + \delta_{gf} AU$
  3.  $Q_c = \alpha_s + \beta_s P_c$
  4.  $P_{gm} = \alpha_{gm} - \beta_{gm} (NS_{gm} + Y_{gm} D_e) - \gamma_{gm} NS_{sm} + \delta_{gm} AU$
  5.  $P_{co} = \alpha_{co} - \beta_{co} (NS_{co} + Y_{co} D_e) - \gamma_{co} NS_{so} + \delta_{co} RCE$
  6.  $P_{ddg} = \alpha_{ddg} P_{gm} + \beta_{ddg} P_{gf} + \gamma_{ddg} P_{co}$
  7.  $Q_c = D_c + D_e + X_c$
- endogenous:  $P_c P_{gf} P_{gm} P_{co} P_{ddg} D_c Q_c$

### Measuring the Effects of Supply and Demand shifts on Corn and Byproduct Markets

Many expect a major expansion in corn processing demand due to changing health and energy market regulations (Renewable Fuels Association). At the same time, a continuation of 1 or 2 bu/acre of annual yield growth could also add considerably to corn supply over the next decade. Supply shifts could occur abruptly if California's MTBE ban is implemented suddenly, or if adoption schedules for a national MTBE ban are accelerated. But based on past experience, the supply shift will more likely be characterized by steady growth. In any event, the overall magnitude of supply and demand shifts are both uncertain and subject to discussion.

Accordingly, consider a hypothetical 100 mil. Bu shift in corn demand in table 2. Baseline data for the 2001 crop year is also included for comparison.

First, the demand expansion increases the corn price by \$.027/bushel. The implied corn supply elasticity to a 2.0 bil. Gallon ethanol industry that uses 800 million bushels of corn annually is  $E=8.9$ . Despite the inelastic structure of the overall corn market then, the price impacts of



processing in the corn market are moderate. This occurs because corn production and corn demand are both allowed to adjust over a few years.

However, increased corn processing would mean higher supplies and reduced prices for byproducts. According to our price response estimates, the gluten meal price would fall to \$211.29/t, which is below the protein equivalent of the soy price. Similarly, the estimates show the corn oil price, 13.48c/lb below the soy oil price. The gluten feed price actually rises slightly, to \$60.69/t, owing to the close competition with rising corn prices. Distillers grain prices are a composite of the three components, but decline slightly, owing to the importance of protein and oil.

From the viewpoint of corn processors, the corn increase and the byproduct declines are both adverse price movements. This magnifies the increases in net corn costs, which are \$.065/bu for dry mills and \$.151/bu for wetmills.

If the processing demand shift occurred in isolation then, the gluten meal and corn oil price declines would probably be limited by prices in the dominant substitute markets. Column 4 of table 2 summarizes the price and cost outcomes when gluten meal and corn oil price equivalently with soy products. The main feature of these results is that higher byproduct prices moderate the net cost increases for processors. The implied net cost elasticity to the ethanol industry, after accounting for price floors, is 2.7, much lower than the corn price elasticity.

The effects of a Corn supply shift are shown in table 3. The 100 million bushel external increase in corn production is actually a conservative estimate of the annual expansion that can be associated with new technology—a production/trend regression over the 1975-2001 period gave an annual increment of 122 million bushels. The estimates of table 3 assume that corn feed consumption absorbs all of the supply increase, because corn processors do not expand their market with lower corn input costs. Hence the gluten meal and corn oil prices are unchanged with the supply shift. The corn price declines by \$.027/bu, which matches the price increase associated with a demand shift of the same magnitude. Also, the gluten feed and the DDG price both decline slightly with the corn price.

### **Summary and Conclusions**

This report has examined the response of price to changing marketing volume for the corn market and the byproducts of the corn processing industry. In most cases, the estimations confirm downward-sloping demand and close substitution between the byproduct and the market for a dominant substitute commodity. The results suggest that the byproduct markets price in proximity to larger markets; gluten feed is close to the nutrient content of corn; gluten meal prices are close to the protein content of soy meal, and corn oil usually obtains a moderate premium over soy oil.

The price response estimations were used to measure the impact of a corn demand shift on the corn processing industry. Summary measures of the agriculture sector's ability to accommodate

demand expansions were developed. The elasticity of excess supply for corn offered to the ethanol industry is about 8.9 with respect to the corn price. A similar elasticity for net corn cost over the range is smaller, at 2.7, but it is still elastic in the range where byproduct supply increases induce price declines and magnify the net corn cost increases. With larger expansions, the net cost elasticity will increase, because byproduct price declines will be limited by the larger markets.

Estimates of new corn processing demand range from 200 mil bushels with California's MTBE ban to 500 mil bushels with renewable fuels standard in the current version of the energy bill. Corn price increases on the order of \$.05/bu or net corn costs on the order of \$.10/bu could be expected if this policy were implemented at once, but with enough forward notice that farmers can expand their output. But the California ban may be one event in a growing market for industrial products. In this context, the corn price and net cost increases will be offset by a few years of supply expansion.



## References

- Gallagher, Paul, "Some Productivity-Increasing and Quality-Changing Technology for the Soybean Complex: Market and Welfare Effects," *American Journal of Agricultural Economics*, 80(1998):165-74.
- McKinzie, L., PL. Paarlberg, and I.P. Huerta, "Estimating a Complete Matrix of Demand Elasticities for Feed Components Using Pseudo Data: A Case Study of Duch Compound Livestock Feeds." *Eur. Rev. Agr. Econ.* 13(1986):23-42.
- Renewable Fuels Association, "Replacing MTBE with Ethanol in Reformulated Gasoline", [www.ethanolrfa.org/let\\_position\\_mtbe.shtml](http://www.ethanolrfa.org/let_position_mtbe.shtml), November 13, 2002.
- Surry, Y. and G. Moschini, "Input Substitutability in the EC Compound Feed Industry." *European Review of Agricultural Economics*, II(1984):455-464.
- Thurman, W. And M. Wohlgenant, "Consistent Estimation of General Equilibrium Welfare Effects." *American Journal of Agricultural Economics* 71(1989):1041-45.
- Tomek, W. G. And K L. Robinson, *Agricultural Product Prices*, Cornell University Press, Ithaca, 1990.
- Tweetin, Luther G. "The Demand for United States Farm Output," *Stanford Food Research Institute Studies* 7(1967):332-445.
- Weigel, J.C., D. Loy and L. Kilmer, *Feed Co-Products of the Corn Wet Milling Process*. Iowa Department of Agriculture and Land Stewardship, 1997a.
- Weigel, J.C., D. LOY and L. Kilmer, *Feed Co-Products of the Corn Dry Milling Process*. Iowa Department of Agriculture and Land Stewardship, 1997b.

Table 1a. Price Equation Estimates for Corn and Wet Mill By-Products

Dependent Variable:	Independent Variables:			Net Supply, Direct		Net Supply, Indirect		Demand Shifter		R <sup>2</sup>	D.W.	$\bar{S}$
	Intercept			(Coefficient,	Variable)	(Coefficient,	Variable)	(Coefficient,	Variable)			
PC (corn)	-1.0616 (0.49)	-0.00146 (7.02)	NSC					+0.16006 (1.57)	GCAU	.812	1.4	0.42
PGF (gluten feed)	106.03 (0.75)	-0.00851 (1.42)	NSGF	-0.0449 (4.28)	NSC			+3.7516 (1.57)	GCAU	.810	1.5	21.62
PGM (gluten meal)	-174.50 (0.45)	-0.2384 (2.53)	NSGM	-0.0133 (1.33)	NSSM			12.3593 (1.77)	GCAU	.701	1.3	46.48
PCO (corn oil)	81.1775 (12.08)	-0.0365 (4.05)	NSCO	-0.0058 (2.09)	NSSO			0.2962 (1.44)	RCE	.75	1.2	7.03

Table 1b. Price Equation Estimate for Distilled Dried Grain

Dependent Variable:	Independent Variables:									
			(Coefficient,	Variable)	(Coefficient,	Variable)	(Coefficient,	Variable)		
PDDG (dist. dry grain)			+0.88845 (7.74)	PGF	+0.1244 (2.78)	PGM	+0.2029 (0.55)	PCO	.994	1.7 13.4



**Table 2. Price and Output Effects of a 100 Million Bushel Expansion in Corn Processing Demand**

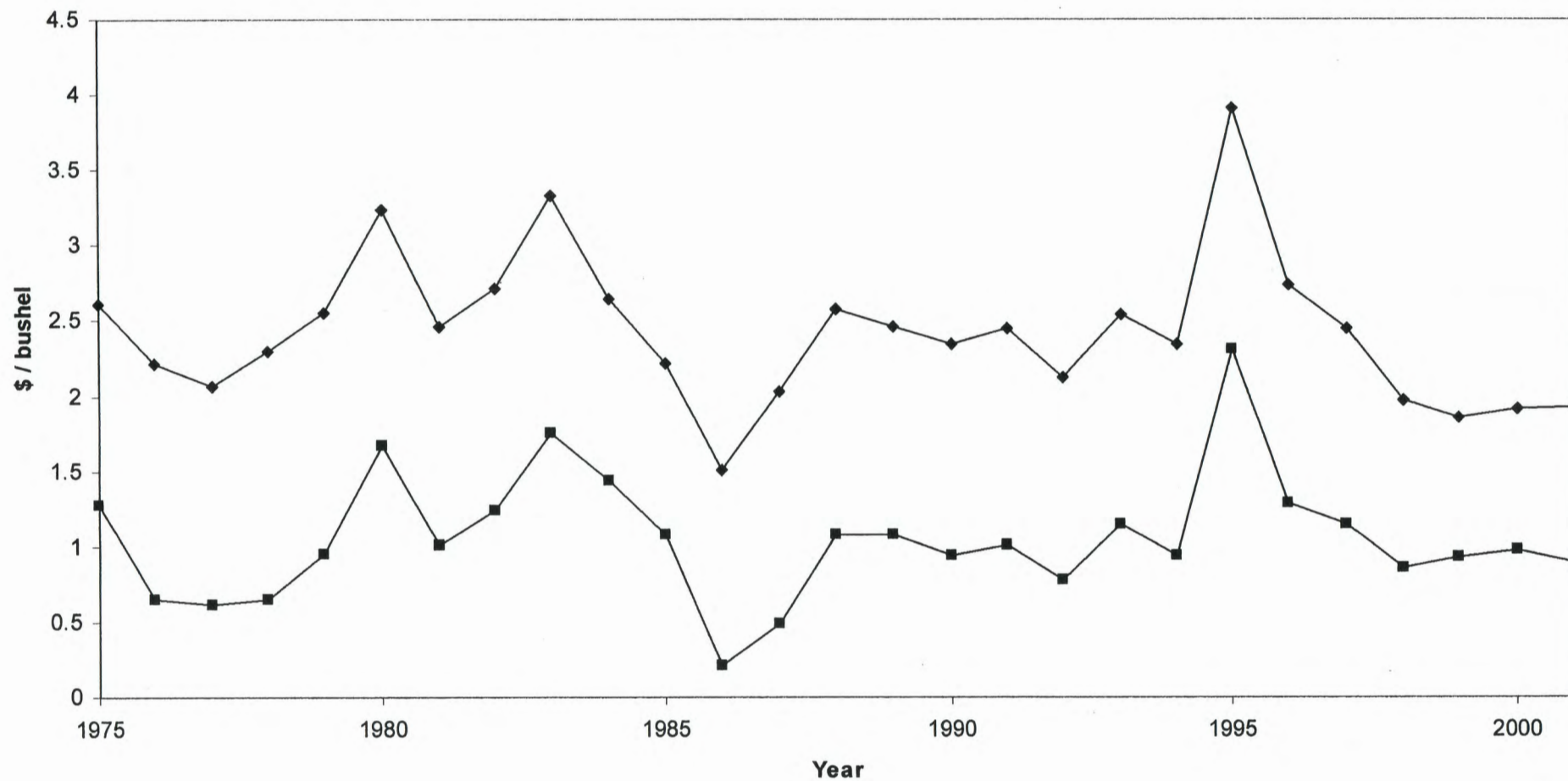
Variable	Units	Variable	2001 Baseline Level	Level with Demand Shift	Floor Price for By-Products	Level with Demand Shift and Floor Price
Corn Price	\$/bu	PC	1.92	1.947		1.947
Gluten Feed	\$/t	PGF	59.87	60.69	53.92 (TDN equivalent corn price)	60.69
Gluten Meal	\$/5	PGM	243.56	211.29	225 (protein equivalent soymeal price)	225.00
Distilled Grain	\$/5	PDDG	78.48	74.13		76.12
Corn Oil	¢/lb	PCO	19.14	13.48	16.46 (soy oil price)	16.46
Net Corn Cost (wet mill)	\$/bu	NCC <sub>w</sub>	.8965	1.047		0.9841
Net Corn Cost (dry mill)	\$/bu	NCC <sub>D</sub>	1.225	1.290		1.273
Corn Output	mil bu	Q <sub>C</sub>	9807	9888.7		9888.7
Corn Demand	mil bu	D <sub>C</sub>	7907	7888.7		7888.7

**Table 3. Price and Output Effects of a 100 Million Bushel Expansion in Corn Supply**

Variable	Units	Variable	2001 Baseline Level	Corn Supply Increase 100 mil bu
Corn Price	\$/bu	PC	1.92	1.893
Gluten Feed	\$/t	PGF	59.87	59.05 (53.92)
Gluten Meal	\$/t	PGM	243.56	243.56 (\$225/t)
Distilled Grain	\$/t	PDDG	78.48	77.75
Corn Oil	¢/lb	PCO	19.14	19.14 (16.4)
Net Corn Cost (wet mill)	\$/bu	NCC <sub>w</sub>	.8965	.8754
Net Corn Cost (dry mill)	\$/bu	NCC <sub>d</sub>	1.225	1.2025
Corn Output	mil bu	Q <sub>c</sub>	9807	9825.2
Corn Demand	mil bu	D <sub>c</sub>	7907	7925.27



Figure 1. Corn Price and Net Corn Cost: 1975 to 2001 Crop Year



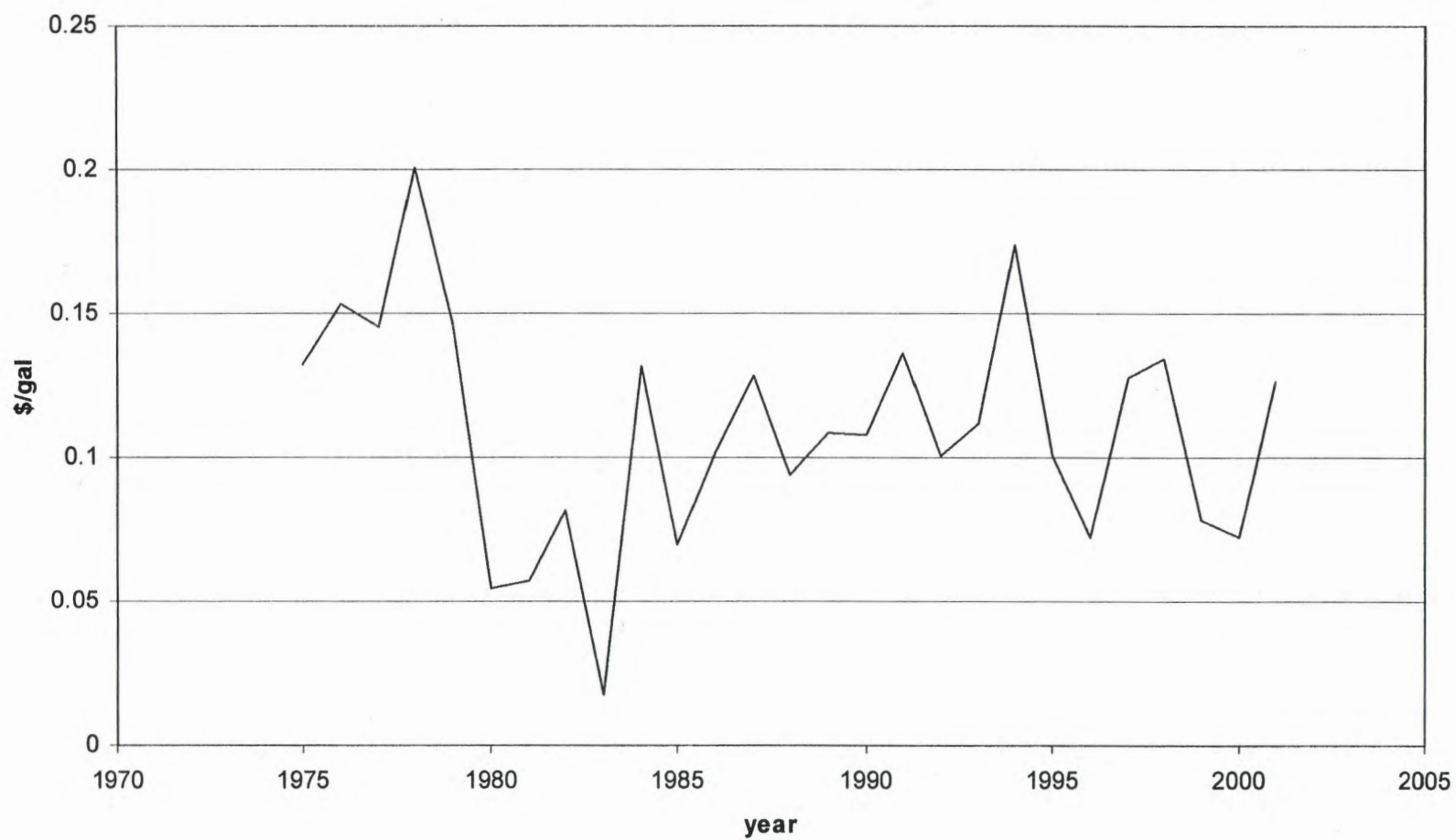
**Figure 1a. Revenue Difference: Wet - Dry Mill**



Figure 2: Price Comparisons for Corn By-Products: 1975 to 2001 Crop Years

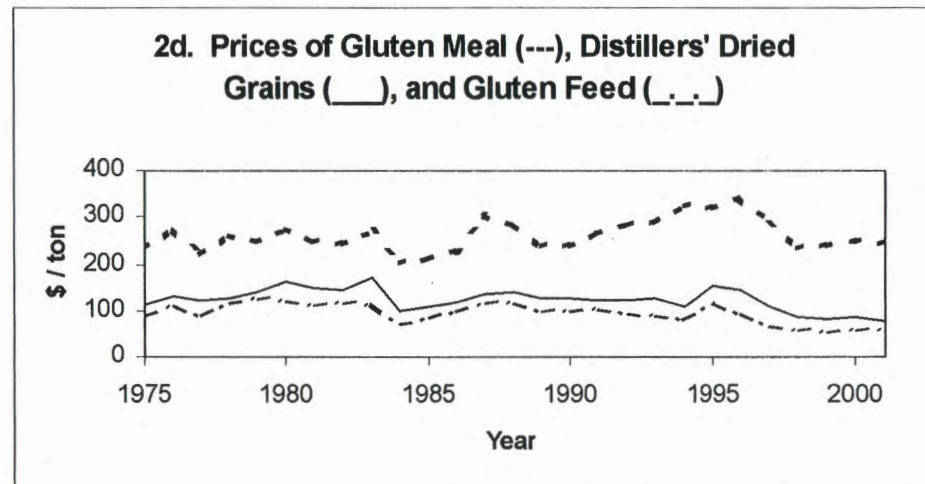
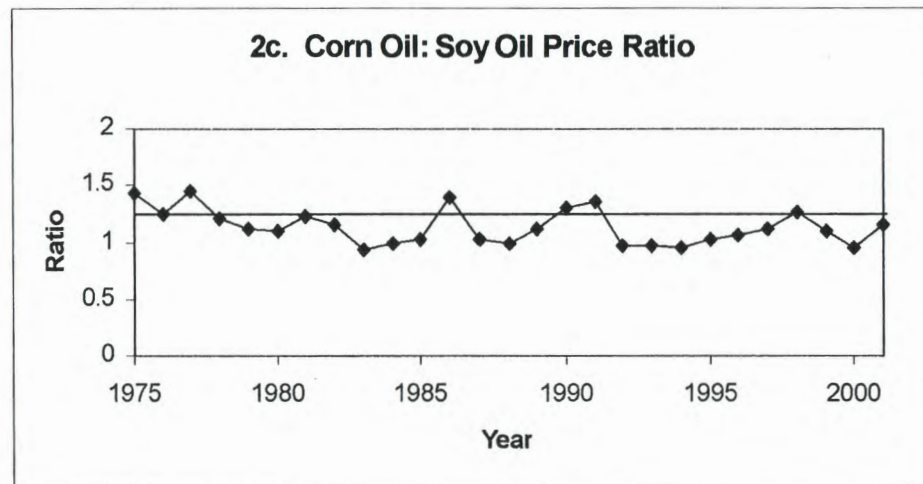
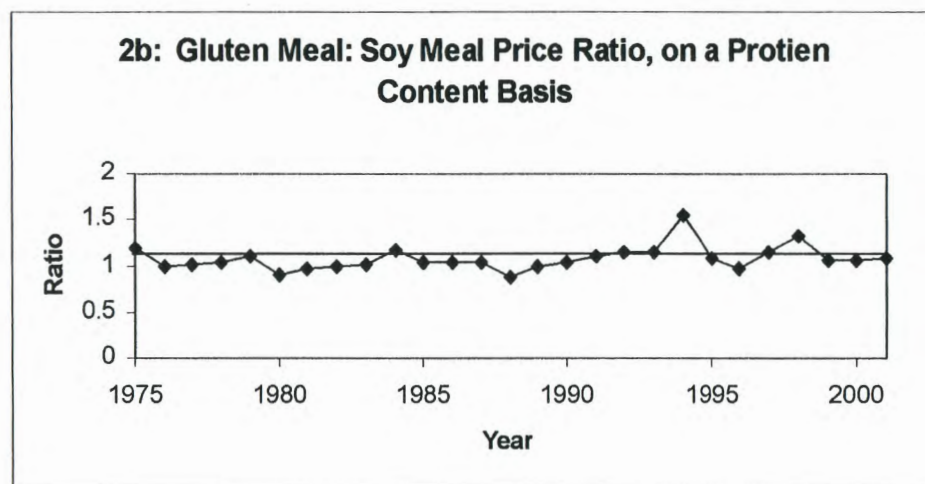
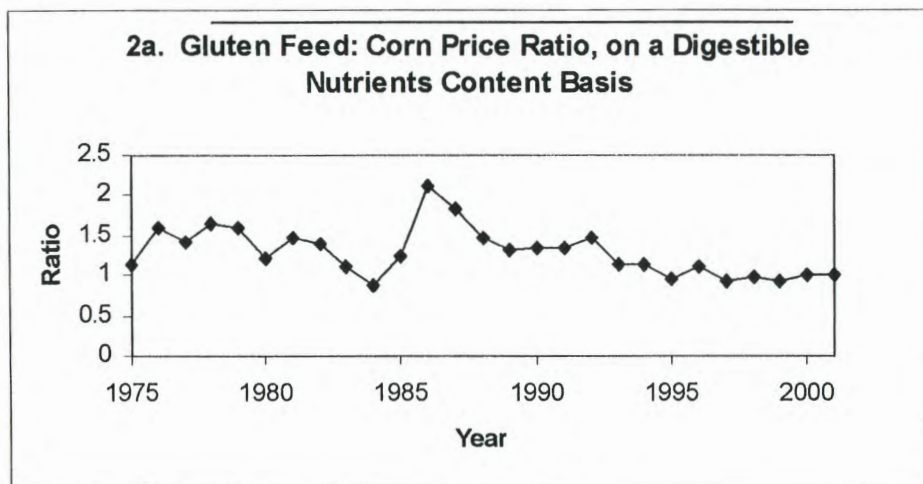


Figure 3. The Case of Demand Substitutes with Given Supply

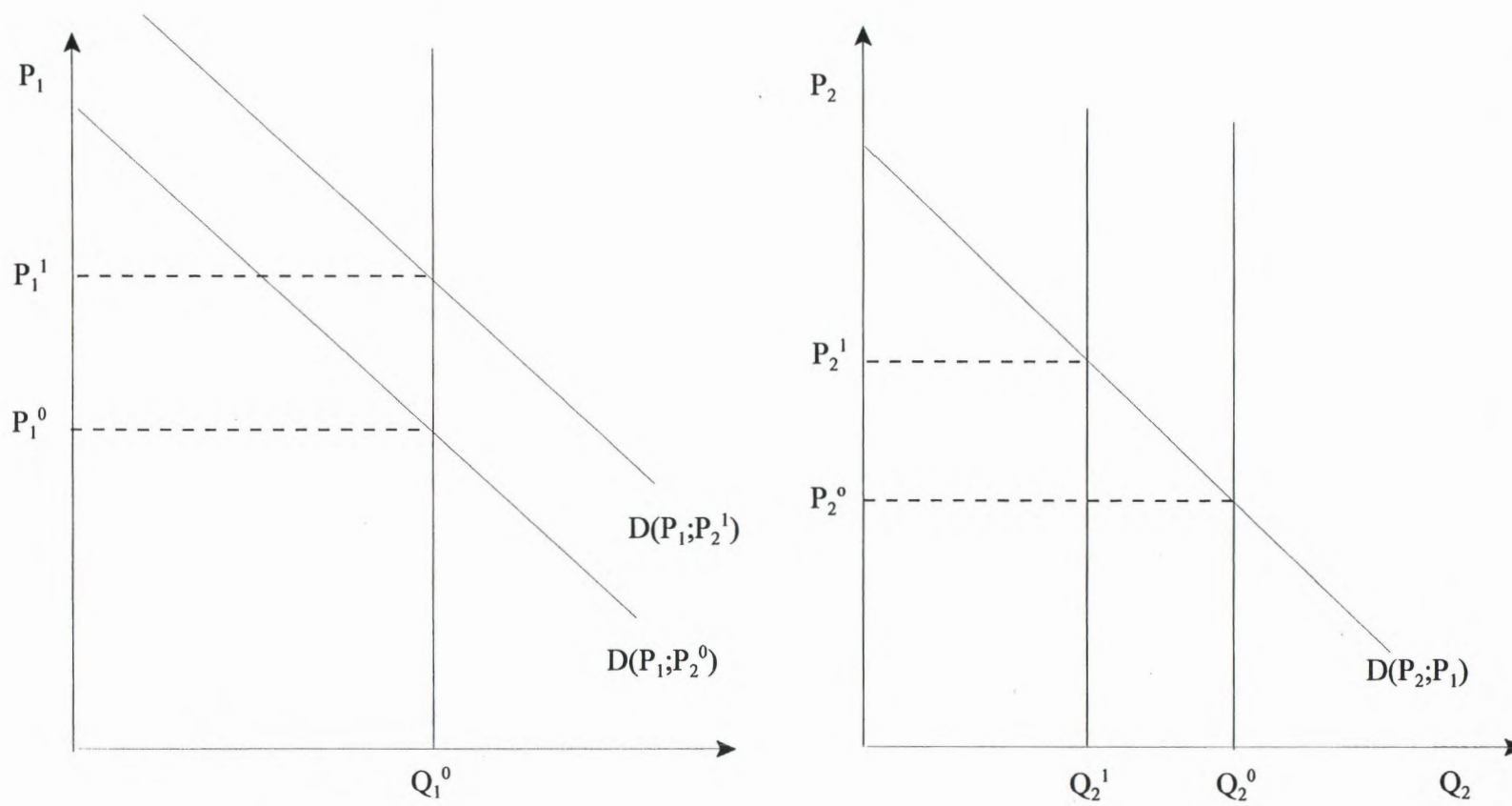
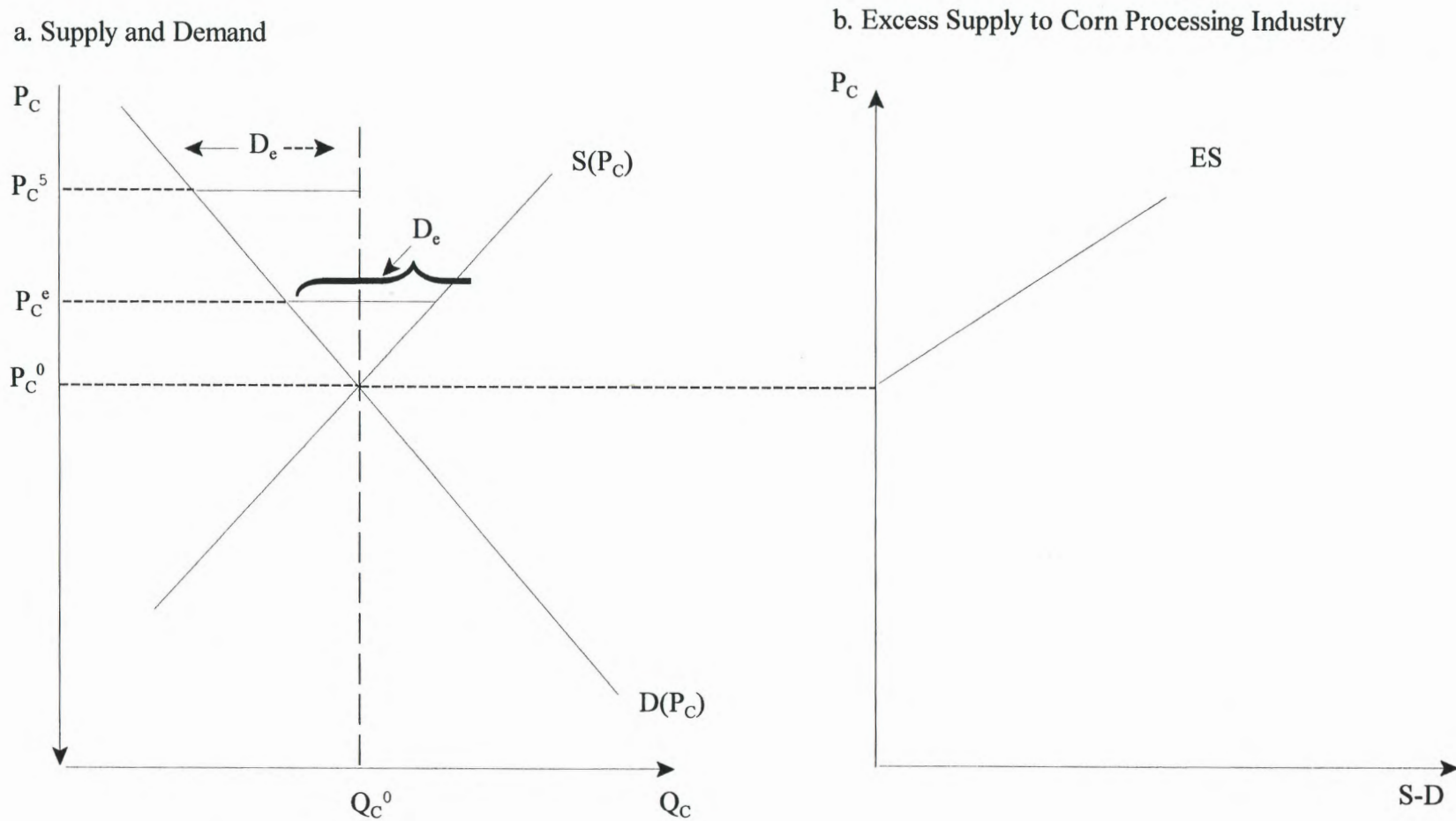




Figure 4. Short Run and Long Run Response to a Corn Demand Expansion



**Table A. Corn Processing By-Products, Crop Year Production and Exports**

		Production	Exports	Percent
	<u>Units</u>			
Corn Gluten Feed	1,000 tons	10,402	4,151	40%
Corn Gluten Meal	1,000 tons	2,041	729	36%
Corn Oil	mil lbs	2,388	689	30%
Distilled Grain	1,000 t	2500	799	32%