A MODEL OF IMPERFECT COMPETITION USING MARGINAL INPUT AND OUTPUT PRICES: APPLICATION TO THE BEEF PACKING INDUSTRY

1998 AAEA Meetings Selected Paper

Abstract

Based on Diewert s idea that models under competition can be generalized to imperfect competition using marginal prices, we develop a test for imperfect competition in the beef packing industry. Our model is more general and flexible than those depending on empirical estimates of the input supply and output demand elasticities.

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A Model of Imperfect Competition in the Beef Packing Industry With Marginal Input and Output Prices

Introduction

Market concentration in the beef packing industry has increased rapidly over the past few decades as firms in the industry have consolidated.[1] The Herfindahl-Hirschman index, which measures the sum of the squared market shares of firms in the industry, for steer and heifer slaughter surpassed the 1800 mark in the early 1990s. Thus, the industry is considered to be highly concentrated based on the US Department of Justice's and Federal Trade Commission's *Horizontal Merger Guidelines*. Because of the high level of market concentration, there is concern that beef packing firms are exercising market power in the purchase of finished cattle by keeping cattle prices below competitive levels, and in the sale of packed beef by keeping prices above competitive levels.

However, as indicated in the *Horizontal Merger Guidelines*, an increase in market concentration in itself is not enough to raise concerns about adverse competitive effects. If a market is contestable, that is, one in which there is free entry and exit, firms in the industry must set price equal to marginal cost (Baumol). Not doing so would invite entry. The beef packing industry can most accurately be described as contestable because there are few barriers to entry. On the output side, imported beef competes with US beef so that high prices for packed beef would induce entry in the form of importation. On the input side, some may argue that spatial characteristics of the market create a barrier to entry. If the minimum efficient plant scale is large, and Ward suggests that it is for beef packing, then efficient size plants must have access to a large number of cattle to operate at capacity. Yet Hayenga, Koontz, and Schroeder found that the market for cattle is national in scope, with some cattle being shipped over 1,000 miles to slaughter. This suggests that packing plants may have access to sufficient numbers of cattle to operate efficiently regardless of location.

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[1] A history of consolidations and plant construction since 1961 for the three largest packers, IBP, ConAgra, and Excel, can be found in Azzam and Anderson.

Most previous studies of the beef packing industry have found evidence that firms, at least part of the time, are exercising market power in the purchase of finished cattle (Schroeter, Azzam and Pagoulatos, Schroeter and Azzam 1990, Azzam, Azzam and Park, and Koontz, Garcia, and Hudson) or are exercising market power in the sale of packed beef (Schroeter and Schroeter and Azzam 1990). However, all of these studies are fairly restrictive in their assumptions. First, they assume a fixed proportional relationship between finished cattle input and packed beef output, yet Wohlgenant found evidence of substantial substitution possibilities between farm inputs and marketing inputs for beef and veal. Also, Goodwin and Brester concluded that technological changes in the food industry as a whole have allowed for greater input substitutability. Second, the studies that attempt to measure simultaneously the degree of market power in both the input market and the output market assume that it is equal in both markets (Schroeter and Schroeter and Azzam 1990). Finally, the results of some of these studies may depend on the specification for the input supply equation for finished cattle and the output demand equation for packed beef (Azzam and Pagoulatos, Azzam and Park, Schroeter, Schroeter and Azzam 1990, and Stiegert, Azzam, and Brorsen).[2] Previous studies by Muth and by Muth and Wohlgenant, which allow for variable proportions, did not find evidence of market power in the output and input markets for the beef packing industry, but the results of each of these studies depend on the specification of input supply and output demand.

The goal of this paper is to develop a more general model of the beef packing industry to test for market power in either the input market or the output market with relatively few restrictions placed on the model. It is based on the idea that the profit function under competition can be generalized to the monopoly situation by replacing observed output market prices with the shadow or marginal prices of output (Diewert 1974, 1978). Likewise, by replacing the observed input market prices with the shadow or marginal price of the inputs, the profit function can be generalized to the monopsony situation. To go one step further and make the model even more

[2] Modeling the input supply equation for cattle can be particularly difficult. Empirical estimates frequently yield negative own-price slopes because, if cattle prices are rising, producers will retain heifers to add to the breeding stock rather than marketing them for slaughter in the current period (see Rosen).

general, the marginal prices can be modeled in such a way that they represent varying degrees of market power between the two extremes of competition and monopoly or monopsony.

This method avoids the need to estimate input supply elasticities or output demand elasticities; therefore, the results are not sensitive to the specification of either. However, because these elasticities are components of the measures of market power, it is not possible to identify explicitly the degree of market power in each market. It is possible, though, to test for market power. If competition is rejected, the model results will provide information on the degree of distortion implied by market power. In the following section, the expressions for marginal input and marginal output prices are developed.

Marginal Input and Output Prices in the Beef Packing Industry

The profit equation of the j^{th} beef packing firm in the industry, allowing for variable proportions, can be represented by

$$(1) \quad \pi_j = p \cdot f_j(\mathbf{x}) - \mathbf{w}' \cdot \mathbf{x}$$

where p is output price, $f_j(\mathbf{x})$ is the production function given the vector of inputs, $\mathbf{x}$, and $\mathbf{w}$ is a vector of input prices. The first-order condition with respect to the level of finished cattle input, x_1, allowing for imperfect competition in the packed beef market and in the finished cattle market, is

$$(2) \quad \frac{\partial \pi_j}{\partial x_{1j}} = p \cdot \frac{\partial f_j(\mathbf{x})}{\partial x_{1j}} + \frac{\partial p}{\partial Q} \cdot \frac{\partial Q}{\partial q_j} \cdot \frac{\partial f_j(\mathbf{x})}{\partial x_{1j}} \cdot q_j - w_1 - \frac{\partial w_1}{\partial X_1} \cdot \frac{\partial X_1}{\partial x_{1j}} \cdot x_{1j} = 0$$

where Q is total industry output of packed beef, $q_j = f_j(\mathbf{x})$, and X_1 is total industry purchases of finished cattle. Converting to elasticity form, equation (2) can be rewritten as the following:

$$(3) \quad p\left(1 + \frac{\theta_j}{\eta}\right)\frac{\partial f_j(\mathbf{x})}{\partial x_{1j}} = w_1\left(1 + \frac{\phi_j}{\varepsilon}\right)$$

where $\eta = \frac{\partial Q}{\partial p} \cdot \frac{p}{Q}$ is the output market demand elasticity for packed beef, $\theta_j = \frac{\partial Q}{\partial q_j} \cdot \frac{q_j}{Q}$ is the output conjectural elasticity of firm j, $\varepsilon = \frac{\partial X_1}{\partial w_1} \cdot \frac{w_1}{X_1}$ is the input market supply elasticity for finished cattle, and $\phi_j = \frac{\partial X_1}{\partial x_{1j}} \cdot \frac{x_{1j}}{X_1}$ is the input conjectural elasticity of firm j. The value of θ_j ranges from zero (perfect competition) to one (monopoly). The value of ϕ_j also ranges from zero (perfect competition) to one (monopsony). Intermediate values of θ_j and ϕ_j between zero and one represent intermediate degrees of market power in the output market or in the input market respectively.

To obtain an industry-wide expression for equation (3), further assumptions are necessary for aggregation. In most studies of market power, one of two aggregation approaches is taken.[3] The first approach is to assume that firms are identical in their technologies and thus they have the same conjectural elasticities in equilibrium (Appelbaum, Azzam and Pagoulatos, Holloway, Lopez, Murray, Schroeter, Wann and Sexton). The second approach is to aggregate a firm-level expression by averaging it over firms or by summing its share-weighted firm-specific components (Azzam and Schroeter 1991 and 1995, Koontz, Garcia, and Hudson, and Schroeter and Azzam 1990 and 1991). The approach taken in this study, which is outlined in the appendix, falls into the latter category.

The result of aggregation is the following industrywide counterpart to equation (3):

$$(4)\quad p\left(1+\frac{\theta}{\eta}\right)\frac{\partial f(\mathbf{x})}{\partial x_1} = w_1\left(1+\frac{\phi}{\varepsilon}\right)$$

The expression for the marginal output price is thus $p^* = p\left(1+\frac{\theta}{\eta}\right)$ and, likewise, the expression for the marginal input price is $w_1^* = w_1\left(1+\frac{\phi}{\varepsilon}\right)$.

An Empirical Model of the Beef Packing Industry

As suggested by Diewert (1974, 1978), marginal prices obtained under imperfect competition can replace the observed market prices in an indirect profit function. The marginal prices derived above are inserted into a normalized quadratic profit function for a representative firm (Diewert and Ostensoe). The advantages of this functional form is that it is flexible and can allow for nonconstant returns-to-scale technology. By applying Hotelling's lemma to the indirect profit function, normalized on p_1, we obtain the following general expression for output supply and input demand:

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[3] A third approach is to ignore the issue of aggregation (Azzam and Park) or to argue that firm-level conditions are appropriate at the industry level (Azzam).

$$(5)\quad y_i = \left(\sum_{i=1}^{M}\alpha_i z_i\right)\sum_{j=1}^{N} a_{ij}\left(\frac{p_j}{p_1}\right) - \frac{1}{2}\beta_i\left(\sum_{i=1}^{M}\sum_{j=1}^{N} b_{ij}\cdot z_i\cdot\frac{z_j}{z_1}\right) + \sum_{j=1}^{N} c_{ij}z_j + \beta_i\sum_{j=1}^{N} b_j\left(\frac{z_j}{z_1}\right) + \frac{1}{2}\beta_i b_0\frac{1}{z_1} + c_i$$

for $z_1, \ldots, z_M$ capital stock inputs and variable outputs and inputs with prices $p_1, \ldots, p_N$. Because of the normalization on p_1, $a_{1i} = a_{i1} = 0$ for $i = 1, \ldots, N$; $b_{1j} = b_{j1} = 0$ for $j = 1, \ldots, M$; and $b_1 = 0$. The last three terms in equation (5) allow for nonconstant returns-to-scale technology. If constant returns to scale correctly characterizes the industry, then $b_0 = 0$; $b_2 = 0$, $\ldots$, $b_M = 0$; and $c_1 = 0, \ldots, c_N = 0$.

Normalizing on the price of marketing inputs used in beef production, allowing for one capital stock variable, z_1, and inserting the marginal output and input price expressions, the estimating equations for output supply and input demand are as follows:

$$(6)\quad q = \alpha_1 z_1\left[a_{22}\cdot\frac{p^*}{w_4} + a_{23}\cdot\frac{w_1^*}{w_4} + a_{24}\cdot\frac{w_2}{w_4} + a_{25}\cdot\frac{w_3}{w_4}\right] + g_{20} + g_{21}\cdot z_1 + g_{22}\cdot\frac{1}{z_1}$$

and

$$(7)\quad x_1 = -\alpha_1 z_1\left[a_{32}\cdot\frac{p^*}{w_4} + a_{33}\cdot\frac{w_1^*}{w_4} + a_{34}\cdot\frac{w_2}{w_4} + a_{35}\cdot\frac{w_3}{w_4}\right] + g_{30} + g_{31}\cdot z_1 + g_{32}\cdot\frac{1}{z_1}$$

where q is output of packed beef, p^* is the marginal output price of packed beef, x_1 is the input of finished cattle, w_1^* is the marginal input price for finished cattle, w_2 is the wage rate for meatpacking labor, w_3 is an energy cost index, and w_4 is a price index of other marketing inputs. Labor, energy, and other marketing inputs are assumed to be purchased in competitive markets.[4]

From the symmetry restriction on the profit function, the effect of the input price on output supply should be equal but opposite in sign to the effect of output price on input demand. Expanding the expression for the marginal prices in equations (6) and (7), the symmetry restriction implies that

$$(8)\quad a_{23}\left(1+\frac{\phi}{\varepsilon}\right) = -a_{32}\left(1+\frac{\theta}{\eta}\right).$$

[4] Input demand equations for labor and energy could have been derived as well but the quantity data necessary to estimate these equations are not available. Furthermore, the test for imperfect competition does not depend on these equations.

Thus, the estimated coefficients will be equal only if there is perfect competition in the input and output markets, i.e., $\theta = \phi = 0$.[5] However, because η and ε are not estimated explicitly in this formulation, θ and ϕ cannot be identified. If the restriction is rejected, though, the relative magnitudes of a_{23} and a_{32} will provide evidence regarding the level of distortion in the market caused by imperfect competition.

Data Sources

The data used to estimate the preceding model are aggregate annual time-series data for the years 1966 through 1995. Cattle input quantities, wholesale beef quantities, cattle prices, and wholesale beef prices were obtained from the USDA's *Red Meats Yearbook* and *Livestock and Meat Statistics*. The farm price for cattle is the series "slaughter steer prices, choice 2-4, Nebraska, 1100-1300 pounds" in both of these publications. These prices were adjusted for by-product allowances, which were obtained from the USDA's Animal Products Branch of the Economic Research Service. Wholesale beef prices were converted from prices per retail pound to prices per wholesale pound by dividing by 1.5133. The energy price index was obtained from USDA's *Food Cost Review*, and the average hourly meat packing wage was obtained from the Bureau of Labor Statistics' *Employment, Hours, and Earnings.* The consumer price index (CPI), which was used as a proxy for the price of other marketing inputs, was obtained on the Internet from the Bureau of Labor Statistics.

Data for the variables that were used as instruments for the endogenously determined wholesale beef price and farm cattle price were obtained from the following sources. Per capita consumption expenditures and population data were obtained from the *Economic Report of the President.* The retail poultry CPI and the retail pork CPI were obtained from the USDA's *Food Consumption, Prices, and Expenditures.* Inventories of beef cattle were obtained from the USDA's *Red Meats Yearbook* and *Livestock and Meat Statistics*. Corn prices were obtained from the USDA's *Feed Situation and Outlook*. All of the price and expenditure instrumental variables were deflated by the CPI.

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[5] Note that θ/η cannot otherwise equal ϕ/ε because θ and ϕ are non-negative, $\eta < 0$, and $\varepsilon > 0$.

Results of Estimation and Specification Testing

Equations (6) and (7) were estimated jointly by nonlinear three-stage least squares (3SLS) with first-order autoregressive error terms (quasi-first differencing). The parameter α_1 was set equal to one because it is not identifiable in these equations from the other parameters $a_{22}, \ldots, a_{25}$ and $a_{32}, \ldots, a_{35}$. The CPI was used as a proxy for the price of other marketing inputs used in producing packed beef based on the assumption that the price of these inputs moves in proportion to the CPI. Because data are not available on the quantity of capital stock used in the beef packing industry, trend was used as a proxy. Instrumental variables included the exogenous variables (w_2, w_3, and t) as well as variables associated with wholesale demand for packed beef (consumption expenditures, population, pork prices, and poultry prices) and variables associated with the supply of finished cattle (corn prices and cattle inventories).

Both the restricted ($a_{23}=a_{32}$) and unrestricted specifications were estimated. In both equations for both specifications, the first-order autoregressive error parameters were in the range of 0.36 to 0.37 and were significant. Ljung-Box statistics calculated at 6 and 12 lags for both specifications failed to reject the null hypothesis that the resulting residuals were white noise. Thus, this specification of the error structure of the models appears to be correct.[6]

Gallant and Jorgenson's method of testing restrictions in nonlinear models was used to test the symmetry restriction. With this method, the restricted specification is reestimated using the estimated variance-covariance matrix of the unrestricted model. The test statistic is the difference in the number of observations multiplied by the change in objective function values, and the degrees of freedom are equal to the number of restrictions imposed. When the test was conducted for this model, the restriction was not rejected (p-value = 0.148), suggesting that the beef packing industry can be characterized as perfectly competitive in its output market and input market.

The results of estimation for the unrestricted and restricted specifications are presented in Table 1. In general, with the exception of the output supply slope, the estimates of the restricted

[6] Models used to estimate the degree of market power are frequently quasi-first differenced (Azzam and Pagoulatos; Azzam and Park; Koontz, Garcia, and Hudson; Schroeter; and Schroeter and Azzam 1990), but the values of the autoregressive parameters are not always reported.

specification are as expected based on theory, but the estimates of the unrestricted model are not. For the restricted specification, the output supply elasticity, evaluated at the means of the sample period, is -0.07 but not significantly different from zero. This suggests nearly perfectly inelastic output supply. The input demand elasticity, evaluated at the means of the sample period, is -0.44, suggesting inelastic demand for live cattle. In addition, the elasticity of output supply with respect to the input price is negative as expected (-0.33 at the sample means), and the elasticity of input demand with respect to output price is positive as expected (0.36 at the sample means).

Of particular interest are the estimates of the coefficients intended to capture the effects of nonconstant returns to scale (g_{20}, g_{21}, g_{22}, g_{30}, g_{31}, g_{32}). In both specifications, the intercept coefficient estimates (g_{20} and g_{30}) and the $1/z_1$ coefficient estimates (g_{22} and g_{32}) are significant, suggesting that beef packing technology is most appropriately characterized as nonconstant returns to scale. In addition, the Gallant and Jorgenson test was applied to test the restriction that these coefficients are jointly equal to zero. The constant returns-to-scale restriction was strongly rejected (p-values < 0.01) for both the specification in which the symmetry restriction was imposed and the one in which it was not. However, because this is an aggregate model, these results must be evaluated in that context. Although constant returns to scale for the industry as a whole is rejected, it could be rejected in part due to the effects of the size distribution of firms. Individual firms may experience constant returns to scale but when firms are aggregated, some with high-average costs and others with low-average costs, nonconstant returns to scale may appear at the industry level. However, it is important to include these effects in a test for market power.

Conclusions and Extensions

A model of the beef packing industry was developed to test for imperfect competition in either or both the input market for finished cattle and the output market for packed beef. Expressions for marginal input prices and marginal output prices that allow for varying degrees of market power were derived and inserted into a normalized quadratic indirect profit function for a representative beef packing firm that allows for nonconstant returns to scale. An output supply equation and an input demand equation were then derived by Hotelling's lemma. Because of the symmetric relationship between the effect of input price on output supply and the effect of output price on input demand, a cross-equation restriction was obtained that will hold only under perfect competition in both markets.

This model is more general than previous studies of market power in beef packing for four reasons. First, the model does not assume fixed proportions in beef packing, and it allows the degree of market power in the input and the output market to differ. Furthermore, the results of model estimation do not depend on empirical estimates of the input supply elasticity or the output demand elasticity. However, because these elasticities, which are components of the measures of the degree of market power, were not estimated, it is possible to test for market power but not identify the degree of market power. Finally, the model allows for nonconstant returns-to-scale technology.

The model was estimated in quasi-first differences in both restricted (symmetry imposed) and unrestricted form. Using Gallant and Jorgenson's method of testing restrictions in nonlinear models, the null hypothesis that the cross-equation restriction holds was not rejected. Thus both the input market for finished cattle and the output market for packed beef appear to be perfectly competitive. Furthermore, it appears that returns to scale are nonconstant at the aggregate industry level.

Further work needs to be done to determine the sensitivity of these results to other possible data series. In particular, different proxies for the price of marketing inputs used in beef packing and the quantity of capital stock may improve the results of estimation. Estimating the model with these alternative data series would allow us to determine whether the results regarding the test for perfect competition and for constant returns to scale are sensitive to these changes.

Table 1. Results of Nonlinear 3SLS Estimation of Output Supply and Input Demand Equations for Beef Packing, 1966-1995

Regressor	Coefficient	Specification: Unrestricted	Specification: Restricted ($a_{23}=a_{32}$)
Output Supply (Dependent Variable: q)			
$(p/w_4)\cdot z_1$	a_{22}	-7.423 (5.791)	-3.187 (5.551)
$(w_1/w_4)\cdot z_1$	a_{23}	2.900 (9.441)	-2.899 (9.222)
$(w_2/w_4)\cdot z_1$	a_{24}	29.797 (24.277)	20.516 (24.391)
$(w_3/w_4)\cdot z_1$	a_{25}	-1.579 (0.792)	-1.613 (0.808)
Intercept	g_{20}	33,664.78 (3,905.5)	32,625.17 (3,959.8)
z_1	g_{21}	90.405 (63.517)	102.915 (64.649)
$1/z_1$	g_{22}	-52,333.37 (17,165.9)	-49,293.23 (17,504.5)
AR1	—	0.362 (0.026)	0.366 (0.027)
Adjusted R^2	—	0.8450	0.8414
Input Demand (Dependent Variable: - x_1)			
$(p/w_4)\cdot z_1$	a_{32}	13.038 (12.058)	2.899 (9.222)
$(w_1/w_4)\cdot z_1$	a_{33}	-4.502 (19.661)	19.226 (15.844)
$(w_2/w_4)\cdot z_1$	a_{34}	-56.529 (50.685)	-24.757 (47.791)
$(w_3/w_4)\cdot z_1$	a_{35}	2.292 (1.666)	2.201 (1.643)
Intercept	g_{30}	-58,753.65 (8,218.7)	-55,975.82 (8,035.3)
z_1	g_{31}	-78.846 (133.434)	-139.704 (129.094)
$1/z_1$	g_{32}	94,456.41 (36,326.7)	86,161.22 (35,846.4)
AR1	--	0.372 (0.027)	0.378 (0.028)
Adjusted R^2	--	0.7595	0.7411
Objective value * N	--	34.3934	30.5310

Note: Endogenous variables are y, x_1, p, and w_1, and numbers in parentheses are standard errors.

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APPENDIX

Because the output and input conjectural elasticities may take on different values, the aggregation problem needs to be considered in each market individually. In this appendix, the aggregation condition is first obtained for the situation where only input market power exists. Then, it is obtained for the situation where only output market power exists. Finally, it is obtained for the situation where market power exists in both markets but, for each firm, the market shares in the input market and in the output market are equal. In each case, however, the resulting expressions for marginal output prices and marginal input prices are identical.

Aggregation with Market Power in the Input Market

If we assume that the output market is perfectly competitive, and thus, θ_j is zero, but that input market power may exist, then equation (3) becomes

$$\text{(A.1)} \quad p \cdot \frac{\partial f_j(\mathbf{x})}{\partial x_{1j}} = w_1\left(1 + \frac{\phi_j}{\varepsilon}\right).$$

By multiplying through by the input market share, s_j^I, and summing over N firms in the industry, equation (A.1) becomes

$$\text{(A.2)} \quad p\sum_{j=1}^{N} s_j^I \frac{\partial f_j(\mathbf{x})}{\partial x_{1j}} = w_1 \sum_{j=1}^{N} s_j^I\left(1 + \frac{\phi_j}{\varepsilon}\right) = w_1\left(1 + \sum_{j=1}^{N} \frac{s_j^I \phi_j}{\varepsilon}\right).$$

Now, let $\phi = \sum_{j=1}^{N} s_j^I \phi_j$ represent the sum of the share-weighted conjectural elasticities of firms in the industry and let $\frac{\partial f(\mathbf{x})}{\partial x_1} = \sum_{j=1}^{N} s_j^I \frac{\partial f_j(\mathbf{x})}{\partial x_{1j}}$ represent the sum of the share-weighted marginal products of firms in the industry. Then, the industrywide counterpart to equation (A.1) is

$$\text{(A.3)} \quad p\frac{\partial f(\mathbf{x})}{\partial x_1} = w_1\left(1 + \frac{\phi}{\varepsilon}\right) = w_1^*$$

where w_1^* is the share-weighted "marginal price" for finished cattle (x_1). This expression is similar to Stiegert, Azzam, and Brorsen except that they model the combined ratio $\frac{\phi}{\varepsilon}$, which they redefine as M, rather than its individual components. Note that if ϕ=0, then w_1^* equals the perfectly competitive market price for cattle, w_1. If ϕ=1, then w_1^* represents the monopsony price for cattle. If ϕ falls between zero and one, then w_1^* represents the price that firms expect to pay for finished cattle after taking into account the reaction of other beef packing firms in the industry to its purchases of finished cattle.

Aggregation with Market Power in the Output Market

If instead we assume that the input market is perfectly competitive, and thus, ϕ_j is zero, but that output market power may exist, equation (3) becomes

$$\text{(A.4)} \quad p\left(1+\frac{\theta_j}{\eta}\right)\frac{\partial f_j(\mathbf{x})}{\partial x_{1j}} = w_1.$$

By multiplying through by the output share, s_j^O, and summing over N firms in the industry, equation (A.4) becomes

$$\text{(A.5)} \quad p\sum_{j=1}^{N} s_j^O\left(1+\frac{\theta_j}{\eta}\right)\frac{\partial f_j(\mathbf{x})}{\partial x_{1j}} = p\sum_{j=1}^{N}\left(s_j^O + \frac{s_j^O\theta_j}{\eta}\right)\frac{\partial f_j(\mathbf{x})}{\partial x_{1j}} = w_1.$$

Now, assume firms in the industry have equal value of marginal products in equilibrium, that is, $p\frac{\partial f_j}{\partial x_{1j}} = p\frac{\partial f}{\partial x_1}$, and let $\theta = \sum_{j=1}^{N} s_j^O\theta_j$ represent the sum of the share-weighted output conjectural elasticities. Then, the industrywide counterpart to equation (A.4) is

$$\text{(A.6)} \quad p\left(1+\frac{\theta}{\eta}\right)\frac{\partial f(\mathbf{x})}{\partial x_1} = w_1.$$

Now, the share-weighted "marginal price" for packed beef is $p^* = p\left(1+\frac{\theta}{\eta}\right)$. Note that if θ=0, then p^* equals the perfectly competitive market price for packed beef, p. If θ=1, then p^* represents the monopoly price for packed beef. If θ falls between zero and one, then p^* represents the price that firms expect to receive for packed beef after taking into account the reaction of other firms in the industry to its sales in the market.

Aggregation with Input and Output Market Power and Equal Market Shares

An aggregate expression for the first-order condition with market power in both markets can be derived if we assume that each firm has equal market shares in both the purchase of the finished cattle and in the sale of packed beef. Now, its market share can be represented by $s_j = s_j^O = s_j^I$. The summed share-weighted industry expression for equation (3) is then

$$\text{(A.7)} \quad p\sum_{j=1}^{N}\left(s_j + \frac{s_j\theta_j}{\eta}\right)\frac{\partial f_j(\mathbf{x})}{\partial x_{1j}} = w_1\sum_{j=1}^{N}\left(s_j + \frac{s_j\phi_j}{\varepsilon}\right).$$

Again, assume that firms in the industry have equal value of marginal products in equilibrium, but let $\theta = \sum_{j=1}^{N} s_j\theta_j$ and $\phi = \sum_{j=1}^{N} s_j\phi_j$ represent the sum of the share-weighted conjectural elasticities. Then, the industry-wide counterpart to equation (3) is

$$\text{(A.8)} \quad p\left(1+\frac{\theta}{\eta}\right)\frac{\partial f(\mathbf{x})}{\partial x_1} = w_1\left(1+\frac{\phi}{\varepsilon}\right)$$

which can be rewritten as $p^* \cdot \frac{\partial f(\mathbf{x})}{\partial x_1} = w^*$. Hence, by assuming equal market shares in both markets, an expression with marginal prices in both the output and the input markets can be derived.