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Policy Analysis in an Imperfectly Competitive Market: A Conjectural Variations Model for the Food Manufacturing Industry

by

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Introduction

Economic analysis of government policies in agriculture has traditionally been based on the assumption of perfectly competitive markets. Pioneered by Muth, the two-input model of a competitive industry has been extensively used by agricultural economists to quantify the effects of government interventions on equilibrium market prices and quantities (e.g. Floyd; Gardner, 1975 and 1987). Recently, increasing attention has been paid to others sectors of the food industry, especially to food manufacturing and its linkages to agriculture. The government intervenes extensively in the food industry through price-related policy instruments (e.g. price guarantees, production subsidies, output quotas) as well as through regulations that influence the competitiveness of the market (e.g. marketing orders, cartel laws, licensing). Since market structure defines the environment in which price policies become effective, the relationship between the two types of government interventions should be taken into account in policy analysis. This is particularly important when the linkages between production agriculture and food processing, two industries with distinctly different structures, are analyzed.

Contrary to the atomistic structure of farming, individual food processors often hold considerable market shares. In 1982, more than half (29 out of 47) U.S. food processing industries had four-firm concentration ratios of 40 percent or greater. According to Scherer, deviations from perfect competition pose a potential problem in these markets. Connor et al., who consider various aspects of market structure, estimate that in 1977 three-fourth of total industry shipments in food manufacturing came from oligopolistic industries. Although deducing strategic power from market structure is not without risk, there is substantial agreement that many U.S. food processing industries are oligopolistic (Breimyer; Parker and Connor; Freebairn et al.; Greig). The competitive model does not seem to be an appropriate framework for policy analysis in U.S. food manufacturing.

In this paper, the competitive model is extended to allow for strategic firm behavior in food processing. To keep the results general, no specific form of oligopolistic conduct is assumed. Instead, the firms can make any conjecture about the reaction of their rivals. The equilibrium outcomes of the conjectural variations model lie on a continuum between perfect competition and monopoly, and include the Cournot oligopoly. The farm sector is represented by a supply function. Six commonly used government interventions are analyzed with respect to their effects on derived demand for the farm product and the price of the processed food. Three of the policy instruments affect food processing directly, the others indirectly through the farm sector.

The policy elasticities obtained from the conjectural variations model are compared to the corresponding policy elasticities from the competitive model to see if the latter can still be used for predicting the effects of government interventions in industries that are characterized by strategic firm behavior. In a second step, the analysis looks at the effects of market regulation (changes in the degree of competition in an industry) on the effectiveness of the six price-related policies.

The Model

There are *N* firms in the industry. Entry conditions are such that the market is uncontested for relevant profit levels. Each firm uses two inputs to produce a homogeneous output. To avoid aggregation problems, it is assumed that all firms in an industry have the same technology and the production function is twice continuously differentiable and homogeneous of degree one in inputs. The restriction of constant returns to scale (CRS) is a compromise between a completely unspecified technology and a specific functional form. It is weak enough to admit a wide range of technologies, among them CES functions.

Let the production function of a representative firm be $x_i = f(a_i; b_i)$ and industry output $X = x_i + X_{-i}$ (variables indexed by *-i* are industry aggregates excluding firm *i*). Industry input levels are $a = a_i + a_{-i}$ and $b = b_i + b_{-i}$. Input *a* is an agricultural input; *b* is a marketing input. Because of identical firms and CRS, industry production is:

$$X = F(a, b) \quad , \tag{1}$$

where F(.) has the same properties as f(.). Industry demand and input supplies are:

$$X = m(P_X) \qquad m'(.) < 0 \tag{2}$$

$$a = g(P_a) \qquad g'(.) > 0 \tag{3a}$$

$$b = h(P_b) \qquad h'(.) > 0 \quad . \tag{3b}$$

The firms' objective is to maximize profits. The individual firm solves:

$$\max \Pi_i = x_i P_x - a_i P_a - b_i P_b$$

for optimal values of a_i and b_i . As an oligopolist, the firm is aware that the price received for its product is a function of industry output. The profit function is:

$$\Pi_i = f(a_i; b_i) P_x(x_i + X_{-i}) - a_i P_a - b_i P_b \ .$$

Setting the partial derivatives with respect to a_i and b_i equal to zero and aggregating across firms yields the industry's profit maximizing first-order conditions (FOC's):

$$P_x F_a \left[1 + \frac{1+\lambda}{N\eta} \right] = P_a \qquad (4a)$$

$$P_x F_b \left[1 + \frac{1+\lambda}{N\eta} \right] = P_b \ , \qquad (4b)$$

where η is the price elasticity of demand and λ (the conjectural variation term) denotes the belief of an individual firm about the competitors' aggregate output response:

$$\lambda = \frac{\partial X_{-i}}{\partial x_i} \ .$$

Since firms are assumed to be identical, each of them has the same expectation about the competitors' reaction to a unilateral output expansion. The equilibrium concept underlying the conjectural variations model, determined by equations (1)-(4), is a Nash equilibrium in quantities. Each player guesses at the competitors' strategies. The presumed reactions of other firms are taken as given. Equilibrium prices and quantities are such that the FOC's of all participants are satisfied simultaneously for the given economic, technological and behavioral constraints. A firm cannot improve its situation by acting differently.

Different λ's correspond to different oligopoly theories. If $\lambda = 0$, the individual firm believes that output changes on its part do not provoke responses by other firms. The outcome is the Cournot-Nash equilibrium. If $\lambda = N-1$, the other firms are expected to expand output by the same proportion, implying that firm *i* does not perceive a chance to increase its market share at the expense of its competitors. In this case, firm *i* 's profits are maximized when industry profits are maximized and the outcome is collusion (cartel). The industry produces monopoly output and charges the monopoly price. The same equilibrium is obtained when there is only one firm in the industry ($N=1$, $\lambda=0$).

Three situations yield the competitive equilibrium result: the Bertrand conjecture ($\lambda= -1$); a large number of firms (N approaches infinity); perfectly elastic demand ($|\eta|$ approaches infinity). In all three cases, the bracketed terms in (4) are equal to one and industry equilibrium is that of a perfectly competitive market. These situations, however, should be distinguished from the perfectly competitive industry, in which firms are assumed to be price takers so that the bracketed terms in (4) are unity by definition. Apart from these special cases, a broad spectrum of oligopoly outcomes is contained in the conjectural variations model. Any conjecture between -1 and N-1 is reasonable.

Let the bracketed terms in (4) be denoted by Ψ, summarizing the three parameters that determine the degree of market power (N, λ, η). Under the conditions of the model, Ψ is bounded by zero and one. Under imperfect competition, factors are paid less than their marginal value products. The strategic power parameter Ψ reflects the fraction of the marginal value products paid to the factors for a given form of oligopoly. To see that the degree of market power is directly linked to the sum of the input shares in output value, S_a and S_b, write total cost (C) in terms of the FOCs. Factors are paid $P_a = P_xF_a\Psi$ and $P_b = P_xF_b\Psi$ per unit, total factor payments are $C = aP_a+bP_b = P_x\Psi(aF_a+bF_b)$. Applying Euler's identity leads to $C = XP_x\Psi$. Dividing by total revenue:

$$S_a + S_b = \Psi \ . \qquad (5)$$

The greater the degree of oligopoly power, the smaller is the sum of the input shares.

The Policy Elasticities

In this section, comparative static results are derived from the conjectural variations model. The emphasis is on the comparison of the effects of a policy instrument under different types of firm behavior. A policy intervention causes the endogenous variables of the model to move away from initial equilibrium. The marginal effects of such interventions are expressed in total elasticity form. The notation follows

Gardner (1987). For instance, the effect of a subsidy (*s*) on the equilibrium value of input *a* is represented by the elasticity Ea^*/Es, where *E* is the percentage operator and the asterisk indicates an equilibrium value. For simplicity, the asterisk on the endogenous variable is dropped henceforth. The elasticities are 'total' in that all of the endogenous variables are allowed to adjust simultaneously. This should be distinguished from the (partial) elasticities of input supply (e_a, e_b) and output demand (η). The derivation of policy elasticities involves taking total differentials of equations (1)-(4). To keep the algebra manageable, Ψ has to be constant; thus, the restriction of constant elasticity is imposed on the demand function.

Six types of policy instruments are considered. Three of them, (i) a production subsidy; (ii) a subsidy for input *a*; (iii) and a price support for the processed food, are government interventions in the food manufacturing sector. The others are interventions in the farm sector: (iv) a price support for the farm product; (v) a production quota; (vi) and a deficiency payment scheme. The quantity of the farm good (*a*) and the price of the processed food (P_x) are chosen as the endogenous variables of interest. The policy elasticities are given in table 1.

Interventions in the Food Manufacturing Sector

A production subsidy reduces the marginal cost of producing *X*; it is incorporated by modifying the FOC's. The marginal factor costs are reduced by multiplying P_a and P_b on the right-hand side of (4) by 1/s, where s = (1+subsidy rate). In non-intervention equilibrium, s = 1. A subsidy of *k* percent is perceived by the industry as a downward shift of the effective MC curve by the same percentage. As expected, the sign of Ea/Es is positive and the sign of EP_x/Es is negative for the given parameter signs for all admissible values of Ψ. The production subsidy increases factor use and reduces output price.

A subsidy for input *a* reduces the marginal cost of factor *a* to the industry. The first-order condition (4a) is replaced by $P_x F_a \Psi = (1/s) P_a$, where s = (1+subsidy rate). The signs of the policy effects are Ea/Es >0 and EP_x/Es <0. The subsidy increases the use of input *a* and reduces the consumer price. The third policy is a price support for *X*. If output price P_x is controlled, $|\eta|$ -->infinity and the perfectly competitive solution is the only possible outcome in the conjectural variations model. Policy elasticities for this case have been derived elsewhere. They are obtained by eliminating the demand function and treating P_x as exogenous. The ouput supply elasticity EX/EP_x is given in Muth (p.227). Floyd analyzes the effects of changes in P_x on factor markets.

Interventions in the Farm Sector

Farm policies enter the model through modifications of the supply function of *a* . A price support program guarantees farmers an output price above the free-market level. For food processors, this price constitutes an input cost. As a result, farm output is expanded, demand is reduced and a surplus is generated. For simplicity, the problem of surplus disposal is ignored. The policy elasticities are obtained by treating P_a as exogenous and deleting the input supply equation (3a). With input supply eliminated, variations in P_a cause equilibrium adjustments of *a* along its derived demand curve. The own-price elasticity Ea/EP_a is negative (table 1). In the special case of perfect competition (Ψ=1), the own-price elasticity reduces to the corresponding expression derived in Hicks (1963). The price transmission elasticity EP_x/EP_a is positive. A price support for the farm product drives up the price of the processed food.

A production quota for the agricultural product drives a wedge between the MC and the market price. The price of the farm good is determined on the derived demand curve. The difference between P_a and the marginal cost of *a* is the per unit value of the quota right. In order to incorporate the quota, the supply function (3a) is eliminated. Variable *a* assumes the role of a parameter. It can be seen that $Ea/Ea = 1$ (table 1). Since a production quota for *a* is equivalent to a negative Ea, $EP_x/Ea < 0$ implies that an output quota in the farm sector has a positive effect on the price of processed food. In the special case of perfect competition, EP_x/Ea reduces to the corresponding expression in Gardner (1987, p.98, equation 4.15).

A deficiency payment program compensates farmers for the difference between a politically determined target price P_T and the actual market price P_a. Food manufacturers buy the product at the lower market price. The equilibrium value of *a* is determined on the input supply curve (3a). Since $Ea = e_a EP_T$, the effect of the deficiency payment on the farm good is simply $Ea/EP_T = e_a$. The link between the target price and the market price is given by $EP_a/EP_T = (EP_a/Ea)e_a$, where EP_a/Ea is the inverse of the own-price elasticity of derived demand. Therefore,

$$\frac{EP_x}{EP_T} = \frac{EP_x}{EP_a}\frac{EP_a}{Ea} e_a \ .$$

This is the same as the elasticity of P_x with repect to a production quota in the farm sector multiplied by e_a (table 1). A target price above the free-market price implies $EP_T>0$. Thus, $EPx/EP_T<0$; a deficiency payment program reduces the price of the processed food.

Firm Conduct and Policy Effects

The total elasticities in table 1 provide the basis for the prediction of policy effects under oligopolistic competition. Oligopolistic firm conduct is captured by the strategic power parameter Ψ . If the market power parameter (and the conjectural variation term λ) and the input shares in total revenue, S_a and S_b, are known, the formulas can be applied directly. In many cases, it is the factor cost shares that are known. Below, it is shown how the policy elasticities in table 1 can be simplified so that Ψ, S_a, and S_b are replaced by the factor cost shares. Relation (5) makes it possible to write:

$$S_a = \rho\Psi \ \text{ and } \ S_b = (1-\rho)\Psi \ , \tag{6}$$

where ρ and $(1-\rho)$ are the shares of inputs *a* and *b* in total cost. By substituting (6) into the policy elasticities, the strategic power parameter cancels and the input cost shares ρ and $(1-\rho)$ show up in the formulas. The reduced formulas, obtained by setting $\Psi=1$ (perfect competition) and replacing S_a and S_b by ρ and $(1-\rho)$, respectively, are identical to the standard policy elasticities derived from the perfectly competitive model, provided that the factor shares in the standard expression are interpreted as cost shares and not as input shares in total revenue. The major implication is that, if the cost shares are known, the policy elasticities of an oligopolistic industry can be computed solely on the basis of e_a, e_b, η, and the elasticity of input substitution σ . This result holds for all forms of oligopolies captured in the conjectural variations framework. If S_a and S_b are observed instead of ρ, the cost shares can be recovered from:

$$\frac{S_a}{S_b} = \frac{\rho}{1-\rho} \quad . \tag{7}$$

The fact that the competitive-market formulas are valid predictors of policy effects in an oligopolistic environment is not the same as saying that firm conduct has no influence on policy effects. In general, input cost shares are dependent on equilibrium output, which is a function of firm behavior. Once the market has settled into an equilibrium, observed cost shares, combined with other model parameters, uniquely determine the effects of policies. There is no need to know the form of competitive behavior that underlies the observed equilibrium.

Market Regulation and Policy Effects

In this section, the effects of market regulation on the policy elasticities are analyzed. Would a policy become less or more effective if, for instance, the entry conditions, the cartel laws, or the rules for market orders were changed? To clarify this issue, it is assumed that some kind of regulatory measure increases the degree of competition in the market. As a consequence, the initial free-market equilibrium will shift to a new one that is characterized by a greater industry output. The impact of this shift on the policy elasticities hinges on the difference in the input cost share ratios before and after regulation. The cost share ratio is determined endogenously and is dependent on the technical characteristics of the production function as well as on the input supply functions. The change in the cost share ratio associated with an increase in competition can be predicted on the basis of the model parameters. A move towards a more competitive equilibrium increases (+) or decreases (–) the cost share ratio $\rho/(1-\rho)$ according to (σ is the elasticity of substitution between *a* and *b*):

	$e_a > e_b$	$e_a < e_b$
$\sigma > 1$	+	–
$\sigma < 1$	–	+

The cost share ratio is independent of the degree of competition if $e_a = e_b$ and/or if σ=1. In other cases, a change in competition has implications for the cost share ratio. For example, if the supply of the agricultural product is less elastic than that of the non-agricultural input, and if input substitution is easy ($\sigma > 1$), a move towards a more competitive equilibrium will decrease the cost share ratio. The signs in the table are reversed for measures that reduce competition in the industry.

Adding the assumptions of constant e_a, e_b and σ over the relevant range of equilibria, and applying the results from above, it can be determined whether market regulation increases (+) or decreases (–) the policy effects. A general conclusion is that in neither case does the move to a more competitive equilibrium affect the sign of the policy elasticity. Only the magnitudes of the elasticities may change. There are no changes if the supplies of the two inputs are equally price elastic and/or if the elasticity of substitution is equal to one. In most other cases, the changes in the absolute values of the policy expressions can be signed based on the three inequalities: $\sigma >(<) 1$, $\sigma >(<) |\eta|$, $e_a >(<) e_b$. Table 2 summarizes the findings for input substitution elasticities greater than one. (For $\sigma < 1$, reverse the signs in table 2). For instance, for the case mentioned earlier ($\sigma > 1$, $e_a < e_b$), a production subsidy in food manufacturing will be a less effective means of increasing the demand for the agricultural input (Ea/Es) after market regulation than it was before if the substitution effect outweighs the output effect, $\sigma > |\eta|$. On the contrary, the effectiveness of the policy is enhanced if $\sigma < |\eta|$. The potential impact of market regulation on the effect of the same policy on the price of the processed food cannot be signed if $\sigma > |\eta|$. If $\sigma < |\eta|$, the absolute value of (EP_x/Es) increases with the degree of competition.

Conclusions and Extensions

The formulas in table 1 are suitable predictors of policy effects for a continuum of oligopolistic firm behavior, ranging from monopoly to perfect competition. The main conclusion is that these policy elasticities, derived from a conjectural variations model, can be reduced to the standard expressions obtained from a perfectly competitive market. From an empirical perspective, the standard formulas provide valid predictors of the effects of government interventions under imperfect competition as long as observations of the input cost shares are available. For instance, if the observed cost shares are the result of a Cournot-Nash equilibrium, the competitive-market elasticity formulas are correct for this particular type of oligopoly.

If the initial oligopolistic equilibrium shifts to a more competitive one as a result of market regulation, the pre- and post-regulation policy elasticities may differ. With the added assumptions of constant e_a, e_b, and σ over the range of relevant equilibria, qualitative conclusions can be drawn about the impact of market regulation on the effectiveness of policy instruments. It turns out that an increase in the degree of competition never reverses the sign of a policy elasticity. Furthermore, the magnitudes of the elasticities do not change in situations with equal supply elasticities and/or a unitary substitution elasticity. In other cases, the changes in the absolute values of the policy expressions can be signed based on the size of the input substitution elasticity relative to the demand elasticity and the size of the supply elasticity of the agricultural input relative to that of the marketing input.

Similar policy elasticities have been derived from a two-sector model in which agriculture is perfectly competitive and food processing is oligopolistic. The explicit representation of technology and optimizing behavior in the farm sector allows for the analysis of a richer set of farm policies. Although the policy elasticities are convenient tools for predicting the effects of government interventions, they rely on fairly restrictive assumptions. To adapt them to more realistic situations, the author is currently developing an empirical two-sector model of farming and food processing based on flexible production functions. The food manufacturing industry is represented by a dominant firm model.

Based on this empirical model, the price/quantity effects as well as the welfare effects of an array of government interventions in the U.S. food industry will be analyzed. To demonstrate the welfare trade-offs of marginal changes in policy intruments, transfer efficiency curves will be estimated. Simulations will be conducted to show the effects of market structure regulations. The simulations will also explore the sensitivity of the results to different assumptions about economies of scale, input substitution, and the elasticities of input supply and industry demand.

TABLE 1
Policy Elasticities

Interventions in the Food Manufacturing Sector

Production Subsidy

$$\frac{Ea}{Es} = \frac{\Psi e_a \eta (\sigma + e_b)}{D} \qquad \frac{EP_x}{Es} = \frac{\Psi e_a e_b + \sigma(e_a S_a + e_b S_b)}{D}$$

Subsidy for Input *a*

$$\frac{Ea}{Es} = \frac{e_a [\Psi \eta \sigma - e_b(\sigma S_b - \eta S_a)]}{D} \qquad \frac{EP_x}{Es} = \frac{e_a S_a (\sigma + e_b)}{D}$$

Interventions in the Farm Sector

Price Support

$$\frac{Ea}{EP_a} = \frac{\Psi \eta \sigma - e_b(\sigma S_b - \eta S_a)}{D'} \qquad \frac{EP_x}{EP_a} = \frac{S_a(\sigma + e_b)}{D'}$$

Production Quota

$$\frac{Ea}{Ea} = 1 \qquad \frac{EP_x}{Ea} = \frac{S_a(\sigma + e_b)}{D''}$$

Deficiency Payment

$$\frac{Ea}{EP_T} = e_a \qquad \frac{EP_x}{EP_T} = \frac{e_a S_a(\sigma + e_b)}{D''}$$

$$D = \Psi \sigma \eta - \sigma(e_a S_a + e_b S_b) + \eta(e_a S_b + e_b S_a) - \Psi e_a e_b < 0$$

$$D' = \sigma S_a - \eta S_b + \Psi e_b > 0$$

$$D'' = \Psi \sigma \eta - e_b(\sigma S_b - \eta S_a) < 0$$

TABLE 2

Change in the Absolute Value of the Policy Elasticities
Due to an Increase in the Degree of Competition

	Ea/EK		EP_X/EK	
$\sigma > 1$	$e_a < e_b$	$e_a < e_b$	$e_a > e_b$	$e_a < e_b$
Interventions in the Food Manufacturing Industry				
Production Subsidy				
$\sigma > \lvert\eta\rvert$	–	–	ind	ind
$\sigma < \lvert\eta\rvert$	+	+	+	+
$\sigma = \lvert\eta\rvert$	n.c.	n.c.	+	+
Subsidy for Input *a*				
$\sigma > \lvert\eta\rvert$	–	ind	ind	–
$\sigma < \lvert\eta\rvert$	+	ind	+	ind
$\sigma = \lvert\eta\rvert$	n.c.	n.c.	+	–
Interventions in the Farm Sector				
Price Support				
$\sigma > \lvert\eta\rvert$	–	+	ind	ind
$\sigma < \lvert\eta\rvert$	+	–	+	–
$\sigma = \lvert\eta\rvert$	n.c.	n.c.	+	–
Production Quota				
$\sigma > \lvert\eta\rvert$	n.a.	n.a.	+	–
$\sigma < \lvert\eta\rvert$	n.a.	n.a.	ind	ind
$\sigma = \lvert\eta\rvert$	n.a.	n.a.	+	–
Deficiency Payment				
$\sigma > \lvert\eta\rvert$	n.a.	n.a.	+	–
$\sigma < \lvert\eta\rvert$	n.a.	n.a.	ind	ind
$\sigma = \lvert\eta\rvert$	n.a.	n.a.	+	–

ind ... sign indeterminate, n.c. ... no change, n.a. ... not applicable
K ... Policy variable (in general).

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