## The Economic Model

Wohlgenant (1989) and WH introduced the agricultural economics profession to a market-clearing framework in which diverse firms demand farm and nonfarm inputs to produce the product mix of a composite industry. By relaxing the restriction of identical production functions across firms, they account for an industry's heterogeneous food items. They note that even if *each* firm produces its items in fixed-input proportions, because proportions vary across the diverse firms of a food industry, production of the entire industry is variable proportions.[1] The framework equips analysts with a tool for studying market relationships that is more general than the models derived from the traditional assumptions of fixed proportions and identical firms.

Market models of diverse firms generalize competitive market relationships. In particular, they can be used to reconcile the *concept* of competitive markets with the *observation* that: (1) increases in consumer food prices are not fully passed through to farmers (Wohlgenant, 1994); (2) nonfarm input prices and consumer food prices may move in opposite directions; (3) consumers may pay higher markups for higher priced products (George and King); and (4) competitive food industries may earn positive longrun rents (U.S. Department of Agriculture, September 1996). Market models based on fixed-proportions production must appeal to imperfect competition to explain these observations (Wohlgenant, 1999).

Tests of market power using market-level data, then, depend on assumptions concerning the nature of *industry* production. Retail-to-farm price spreads that exceed the marginal cost of transforming farm ingredients to final food products suggest market power, but the formulas used to compute spreads depend on the industry production function.[2] Studies based on fixed-proportions consistently reject the competitive model (e.g., Schroeter, Schroeter and Azzam, Azzam, Azzam and Park, and Koontz, Garcia, and Hudson), whereas WH and Wohlgenant (1989, 1996) just as consistently fail to reject the competitive model for U.S. food industries.[3]

This section presents an overview of the theory used in our empirical analyses. We refer readers unfamiliar with this theory to the cited studies of WH and Wohlgenant (1989, 1996) for a discussion that is more complete than that presented in this section. Readers familiar with the theory can skip to the next section.

At the core of the WH model are a pair of quasi-reduced-form retail and farm price equations for each market and a system of consumer-demand relationships linking the markets. Given a consumer demand schedule, the underlying structural model consists of two market-clearing conditions. The first states that the sum of food supply across the firms of the industry equals consumer demand for the industry output. The second states that the sum of farm ingredient demand across firms of the industry equals farm supply. The *critical feature of the WH model is that an industry's firms are not restricted to possessing identical production functions*. Within this general setup, WH assume that each industry faces an infinitely elastic supply of nonfarm inputs (exogenous nonfarm input prices), and a less-than-infinitely elastic supply of farm ingredients (endogenous farm prices). To simplify the model structure and isolate analysis on retail and farm prices, WH assume the food industry for a particular market consists of all the firms that manufacture, wholesale, and retail the industry's final food products.

[1] Wohlgenant (1999) formally shows that if one analyzes a competitive industry producing a heterogeneous mix of final consumer goods that we treat as a single composite (e.g., beef ), the *observation* that retail-to-farm price spreads widen with increases in consumer food prices (e.g., George and King) implies input substitution. To explain this observation with a fixed-proportions based model for this heterogeneous industry, one must *rule out* the competitive model.

[2] Retail-to-farm price spread formulas used by ERS/USDA (Elitzak) are based on fixed-proportions production. Presumably, formulas based on variable-proportions would yield different magnitudes.

[3] These results are predicted by the theoretical results presented in Wohlgenant (1999).

Based on this structure[4] and on market clearing for farm ingredients and food output, Wohlgenant (1989, 1996) and WH derive the quasi-reduced-form

$$(1)\quad \begin{aligned} lnP_{rj} &= A_{rf}^{(j)}\, lnF_j + \mathbf{A_{rw}^{(j)}}\, \mathbf{lnW} + A_{rz}^{(j)}\, lnZ_j + e_{rj} \\ lnP_{fj} &= A_{ff}^{(j)}\, lnF_j + \mathbf{A_{fw}^{(j)}}\, \mathbf{lnW} + A_{fz}^{(j)}\, lnZ_j + e_{fj} \\ & \qquad j = 1,...,J \end{aligned}$$

in which $lnP_{rj}$ represents the natural logarithm (log) of the retail price in the $j$th market, $lnP_{fj}$ is the log of the price of the farm ingredient used to produce output of the $j$th market, $lnF_j$ is the log of the supply of the farm ingredient used to produce output of the $j$th market. In this study, $lnF_j$ captures changes in domestic supply, and excludes changes in net exports and changes in private and government stocks of farm commodities. $\mathbf{lnW}$ is a vector of logged nonfarm input prices, and $lnZ_j$ is a consumer demand shifter to be defined below. $e_{rj}$ and $e_{fj}$ are model errors on the retail and farm price equations.[5] These two retail and farm price equations are central to this bulletin.

In this framework, consumer demand defines the market, and the total consumer demand shift variable for the $j$th market, $lnZ_j$ represents the effect of all variables that affect demand except the own-retail price for the product. For this bulletin, $lnZ_j$ is derived as follows. Let

$$ln(Q_j /POP) = e_{jj}\ lnP_{rj} + e_{jy}\ ln\ (Y/POP) + \Sigma_{k\neq j}\, e_{jk}\ lnP_{rk} + u_j$$

be a per capita consumer demand relationship for the $j$th product in which $ln(Q_j/POP)$ is the log of per capita consumer demand for the output of the $j$th industry, $lnP_{rj}$ is the log of the own-retail price, $ln(Y/POP)$ is the log of per capita disposable income, $lnP_{rk}\ (k\neq j)$ is the $k$th retail price of a gross substitute or complement to product category $j$, and $u_j$ is an error term. Hence, the $e_{jj}$ is the own-retail price elasticity of consumer demand, $e_{jk}\ (k\neq j)$ is a set of cross-price elasticities of demand, and $e_{jy}$ is the income elasticity of demand for the $j$th good. Based on this relationship, the total demand shifter for the $j$th market is

$$(2)\quad lnZ_j = e_{jy}\ ln\ (Y/POP) + \Sigma_{k\neq j}\, e_{jk}\ lnP_{rk} + lnPOP$$

in which $lnPOP$ is the log of population. $lnZ_j$ does not capture shifts in consumer demand caused by changes in the demand for food away from home, nor does it capture shifts caused by changes in the composition of the population.

The equations 1 are “quasi” reduced because they account for market-clearing in the $j$th market independent of market clearing in other markets.[6] Theory suggests four sets of expected signs on the quasi-reduced forms.

First, Heiner proves that for an industry of diverse firms, an increase (decrease) in the price of an input decreases (increases) an industry’s demand for the input. While this result is standard for an isolated firm and for an industry comprised of identical firms, Heiner’s proof applies to an industry comprised of firms with different longrun average costs. Heiner’s proof does *not* describe the negative slope of the sum of competitive firms’ input demand schedules holding output price constant. It describes instead the slope of industry input demand schedule as the sum of firms’ supply moves along a downward-sloping consumer demand schedule and, output price changes.[7] Braulke showed that Heiner’s proof applies to longrun equilibrium in which firms enter and exit the industry. In equations 1, $A_{ff}^{(j)}$ is the own-price flexibility of an

[4] A brief discussion of the relationship between the structural model and the quasi-reduced form is provided in the Appendix. The reader is referred to Wohlgenant (1989) or Wohlgenant and Haidacher for a more complete discussion.

[5] Constants and deterministic time trends are added to all of the empirical specifications below except the system of consumer demand relationships (Appendix). Only a constant term was added to the consumer demand system.

[6] The quasi-reduced-form equations derive from Heiner’s seminal work and the extensions of this work by Wohlgenant (1989) and WH. In the quasi-reduced-form representation, shifts in the market’s demand schedule are exogenous.

[7] For any single firm, Heiner found that the simultaneous change in the output price caused by the change in input price may trace out a positively sloped input demand for the firm. He found this positive relationship disappears when summing over all firms.

industry's demand for farm ingredients, and theory suggests $A_{ff} < 0$.[8]

Second, the industry's longrun quantity of food supply increases with its own-consumer food price. Heiner, Braulke, Panzar and Willig, and WH show that even if all input prices are exogenous to a competitive industry (flat input supplies), firm diversity implies that positive shifts in consumer demand trace an upward-sloping longrun industry supply function. Theory implies $A_{rz} > 0$.

Third, if firms are identical and farm ingredients are normal factors of production, a decrease in the supply of farm ingredients leads to a contraction of food supply and to an increase in consumer food prices. A *normal* factor of *industry* production is one in which the industry uses more of the factor to produce more output, while an inferior factor is one in which the industry uses less of the input to produce more output. The theory of diverse firms extends the neoclassical result that an increase in farm prices leads to increases in food prices only if farm ingredients are normal factors of industry food production. Since we expect that the aggregate farm ingredients specified here are normal, we expect $A_{rf} < 0$.

Fourth, if farm ingredients are normal factors of industry production and firms are diverse, positive shifts in consumer demand lead to longrun increases in farm prices. For that reason we expect $A_{fz} > 0$.

The theory of diverse firms does not unambiguously sign the response of consumer food prices to changes in nonfarm input prices. The reason is that a marketing input may be an *inferior* factor of production.[9] An increase in the price of an *inferior* factor raises a firm's average costs, but *reduces* its marginal costs. For a competitive industry comprised of identical firms, higher longrun average costs drive firms from the industry, reduce industry supply, and drive up consumer prices. The results may be different if an industry's firms are diverse.

*Inframarginal* firms are bestowed with firm-specific fixed assets that earn rent in the long run. Such firms are bestowed with firm-specific entrepreneurial capacity (Friedman) or location that provides them with a cost advantage over marginal firms (Panzar and Willig). One could argue that the entrepreneurial capacity of inframarginal pork-producing firms in the Southeast United States exceeds that of marginal producers in the Midwest. The cost advantage of inframarginal firms allows them to remain in the industry even as the longrun average cost of other firms is above market price. It follows that even in competitive markets, if the factor is inferior to inframarginal firms, an increase in its prices allows inframarginal firms to increase their supply even in the long run. The increase places downward pressure on output price. On the other hand, if the factor is inferior to marginal firms, their longrun average cost rises above output price. Marginal firms would exit the industry, thereby reducing industry supply and placing upward pressure on the market's average price of output. A negative sign on an element of $\boldsymbol{A}_{rw}$ suggests the associated factor is inferior to *industry* production, and that the positive supply response of inframarginal firms outweighs the negative response of marginal firms[10] (Panzar and Willig).

Theory provides a homogeneity condition. Since consumer demand is homogeneous of degree zero in retail (food) prices and income, and output supply and input demand are homogeneous of degree zero in farm and nonfarm input prices, the market-clearing price equations of (equations 1) are homogeneous of degree zero in farm and nonfarm input prices, retail prices, and income (e.g., WH, Wohlgenant [1989], Chavas and Cox).

The WH framework provides a test of the competitive model. The test is based on the notion that if a firm is

[8] Correspondingly, the retail price equation of (1) is a Heiner-type of industry-level output supply schedule.

[9] The example given here would not hold for the special case of only two inputs (e.g., one farm and one non-farm input). In this two-input case both factors must be normal, and increases in the price of either input raise the output price.

[10] Because firm-level production functions are not identical, a factor of production can be normal for some firms and inferior for others (e.g., older versus modern plants). Hence, a factor is normal (inferior) for an *industry* if the industry uses more (less) of the factor as it increases output. The weighted sums of individual firm-level elasticities determine whether a factor is normal or inferior (WH).

a price taker in both its purchase of inputs and its sales of output its profit function exists, and the symmetric second derivatives of its profit function define reciprocal relationships between a firm's output supply and input demands. Wohlgenant and WH derive an analogous symmetry condition for the group of diverse industry firms. Denoting $S_f^{(j)}$ as the cost share of farm ingredients for the *j*th industry, and to the coefficients in equations 1, WH show that symmetry at the *industry* level implies

$$A_{rf}^{(j)} = -S_f^{(j)} A_{fz}^{(j)}.$$

This condition states that if firms take farm and consumer prices as given, there exists a symmetric response of consumer and farm-level prices.

When studying retail and farm price relationships, analysts are often interested in the elasticity of transmission of farm prices to retail food prices. The *elasticity of price transmission* is the percent change in a retail food price induced by a 1-percent change in the farm price (George and King). Estimates of this elasticity reduce to the farm share if the food industry is competitive and if industry production exhibits constant returns with respect to farm ingredients. The assumption of fixed-proportions production (at the industry level) imposes constant returns with respect to *all* inputs, and therefore ensures transmission elasticities equal to the farm share. The WH model allows us to test whether the elasticity of price transmission equals the farm share within a variable-proportions framework.

Wohlgenant and WH show that in terms of the coefficients of equations 1, the *j*th industry's production displays constant returns with respect to the farm input if

$$A_{rz}^{(j)} = -A_{rf}^{(j)}$$
$$A_{fz}^{(j)} = -A_{ff}^{(j)}$$

hold. Constant returns for an industry imply zero industry profits in the long run. If both the symmetry and the constant returns restrictions hold, the elasticity of price transmission equals the farm share.

The model provides refutable hypotheses concerning oligopsony power. Policymakers often express concern that food producers exert market power when acquiring raw agricultural commodities from farmers. Some point out that captive supplies associated with new marketing arrangements may have changed the market structure so as to favor food producers and keep farm prices below competitive levels (U.S. Department of Agriculture, February 1996). Others counter that such voluntary arrangements may reflect the response to risk in a competitive market (Paul). The WH framework provides a test of the null that food producers acquire farm commodities competitively in national markets.

The test recognizes that if firms exert market power in acquiring farm commodities, a gap would exist between the farm price and the industry's demand for farm ingredients. Shifters on the farm supply function would define this gap.

At the level of the firm, the arguments are as follows. Let $P_{fj} = P_{fj}(F_j, \boldsymbol{S}_j)$ denote the inverse supply function for farm commodities facing the *j*th food industry, where $\boldsymbol{S_j}$ denotes a vector of shifters to this supply function. The first-order condition for profit maximization of a food-producing firm takes the form $MVP = P_{fj} + \lambda f\,(\partial P_{fj} / \partial F)$, where MVP is the marginal value product or firm-level demand for the farm commodity, and $\lambda$ is a market power parameter. $\lambda$ embodies the firm's conjecture about the effect its purchases of farm ingredients will have on the market (Bresnahan, p. 102-104). Note that the term $(\partial P_f / \partial F)$ in the above relationship is a function of $\boldsymbol{S_j}$. When $\lambda \neq 0$, the market level demand shifters, $\boldsymbol{S_j}$, enter the firm's optimization rule and define a gap between the market's farm price and the value of the marginal product for a competitive firm. Hence, when $\lambda \neq 0$, the marginal farm price – the firm's MVP – lies above the average farm price and firms restrict their demand for farm commodities. If $\lambda = 0$, price-taking firms recognize that their purchases impart no effect on the market, the farm price (or the value of the marginal product) equals the MVP as the industry level demand shifters ($\boldsymbol{S_j}$) do not enter firms' optimization conditions.

For a group of nonidentical firms of an industry, the arguments are similar. By eliminating $F_j$ from equations 1, the two equations reduce to

$$(3)\quad P_{rj} = B_f^{(j)} P_{fj} + B_w^{(j)} W + B_z^{(j)} Z_j + v_r.$$

Equation 3 is an industry-level relationship similar to the first-order conditions of a price-taking firm. Under the null of no oligopsony power, the vector of supply shifters, $\boldsymbol{S_j}$, does not appear in equation 3. Under the alternative, $S_j$ explains the gap and

$$P_{rj} = B_f^{(j)} P_{fj} + B_w^{(j)} W + B_z^{(j)} Z_j + \boldsymbol{B_s^{(j)\prime} S_j} + \boldsymbol{v_r} \quad (4)$$

suggests the industry exerts oligopsony power in acquiring farm inputs. Equations 3 and 4 suggest that if industry *j* acquires farm commodities competitively, $\boldsymbol{B_s^{(j)\prime}} = \mathbf{0}$.

This concludes the review of the theory used to interpret the empirical results presented in the remainder of this report. Before we present these empirical results, however, we review the way in which structural change enters our empirical analyses.