Do Alternative Marketing Arrangements Increase Pork Packers' Market Power?

Xiaoyong Zheng and Tomislav Vukina

In this article we use structural econometrics to formally test whether the use of the alternative marketing arrangements (AMAs) by pork packers is the source of their market power on the spot (cash) market for live hogs. We specify the pork packers' conjectures of the change in the industry total market procurement of live hogs through the spot market with respect to their AMAs stocks. The test is carried out using the mandatory price reporting data. Our results show that pork packers have statistically significant market power on the spot market for live hogs, but the source of that market power cannot be narrowed down to the existence of AMAs stocks.

Key words: alternative marketing arrangements, hogs, market power.

During the last quarter century, the swine industry in the United States has experienced two well-recognizable and important tendencies. First, the industry has become increasingly concentrated. In 1980, the top four firms controlled 33.6% of the slaughter of live hogs, and the top eight firms controlled 50.9%, whereas in 2000, the leading four firms had 57.1% share of the packing, and the leading eight firms controlled 80.3% (USDA-GIPSA 2001). Since then, the share of leading companies has surely increased, the most recent event being the acquisition of Premium Standard Farms by Smithfield Foods. Second, for the procurement of market hogs, the industry increasingly relies on the alternative marketing arrangements (AMAs) and less on the spot market.[1] A recently completed survey of hog producers and packers (Vukina et al. 2007) shows that in the 2004/2005 period, only 24% of the market hogs was transacted on the spot/cash markets. As a comparison in 1999, this share was 36% (Grimes, Plain, and Meyer 2004).[2]

Due to the high level of market concentration, a legitimate concern has been raised that pork packing firms could be exercising market power in the procurement of market hogs by keeping live hog prices below the competitive levels. In addition to purely oligopsony issues, another concern could be raised about the increasing reliance on AMAs. One line of thought (espoused in the beef industry studies) accepts the following: because AMAs supplies provide a substantial portion of packers' needs, the demand for spot market animals declines, and assuming that this decrease in demand is not accompanied by an adequate decrease in supply, the cash price will be negatively affected (Schroeder et al. 1993). Another line of thought claims that the price effect of AMAs is neutral because if, for example, 10% of the demand for live animals is removed, so is 10% of the supply, and the net effect on the market is zero (USDA-AMS 1996).

The concerns about the effects of the captive supplies culminated in a legislation proposed as part of the 2002 Farm Bill (subsequently omitted) to ban most packer ownership of cattle. As recently as Fall 2007, the Senate Agriculture Committee passed an amendment to its version of the 2007 Farm Bill that would prohibit packers from owning livestock for more than 14 days before slaughter. Under the proposed amendment to the Packers and Stockyards Act, packers could not "own or feed livestock directly, through a subsidiary, or through an arrangement that gives the packer

---

Xiaoyong Zheng and Tomislav Vukina are assistant professor and professor, respectively, in the Department of Agricultural and Resource Economics, North Carolina State University.

The authors thank three anonymous reviewers and Paul Preckel for their constructive comments, which greatly improved the paper. An earlier version of this article was completed under a contract with the Grain Inspection, Packers and Stockyards Administration (GIPSA), U.S. Department of Agriculture. Any opinions, findings, and conclusions or recommendations expressed in this article are those of the authors and do not necessarily reflect the views of GIPSA or the U.S. Department of Agriculture.

[1] In the cattle industry vernacular, the AMAs are usually known as "captive supplies."

[2] There are significant regional differences in the observed patterns of use of AMAs: a stronger reliance on cash/spot markets and marketing contracts is apparent in the Midwest and a stronger reliance on production contracts and packer ownership of hogs is apparent in the East (Vukina et al. 2007).

Amer. J. Agr. Econ. 91(1) (February 2009): 250–263

DOI: 10.1111/j.1467-8276.2008.01185.x

operational, managerial, or supervisory control over the livestock, or over the farming operation that produces the livestock."[3]

The estimation of market power has been and still is an important part of empirical industrial organization literature. Most of the attention has been directed toward the analysis of output markets (e.g., Appelbaum 1982; Bresnahan 1989), but occasionally the specialized or localized nature of input markets was warranted studying the monopsony/oligopsony issues as well (e.g., Murray 1995). The issue of market power in meat packing has been extensively studied as well, and as seen from Azzam and Anderson (1996), the empirical evidence is rather mixed. For example, Schroeter (1988) found statistically significant monopoly/monopsony price distortions in the beef packing industry. Azzam (1997) and Morrison Paul (2001) found that the cost efficiency effect dominates the market power effect of the industrial concentration in the beef sector.

Numerous studies have been devoted to the investigation of the effects of AMAs on the spot market price. Although the empirical evidence suggests a modest inverse relationship between AMAs and spot market prices, establishing a causal link has been more difficult. For example, using a reduced-form approach, Elam (1992), Hayenga and O'Brien (1992), and Schroeder et al. (1993) all find some evidence of a negative relationship between captive supplies and cash prices at the market level, and Schroeter and Azzam (2003) find the same evidence at the plant level. In addition Crespi and Sexton (2004, 2005) find evidence of bid shading by packers in cattle auctions, citing the use of AMAs as one of the possible underlying contributing factors. Using an equilibrium displacement model, Azzam (1998) showed that noncompetitive conduct by the packers is not a necessary condition for observing a reduced-form negative relationship between the captive supplies and the market price in the cash channel. Therefore, in order to establish or test such a causal link, one needs an econometric model with more structure.

In this article, we use structural econometrics to formally test whether the use of the AMAs by pork packers is the source of their market power on the spot (cash) market for live hogs. We extend Schroeter's (1988) beef packing industry model and specify the packers' conjectures of the change in total market procurement of live hogs through the spot market with respect to their own changes as the explicit functions of their AMAs supply stocks. Testing whether these stocks are significant determinants of the packers' equilibrium conjectures can be taken as a test of whether the use of the AMAs is a source of market power on the spot market for live hogs. The test is carried out using the USDA mandatory price reporting data. Our results show statistically significant market power of pork packers on the spot market for live hogs, but the source of that market power cannot be narrowed down to the existence of AMAs stocks.

Data Description

The main data set used in this study comes from the U.S. Department of Agriculture, Agricultural Marketing Service, Mandatory Price Reports (MPR) data.[4] The MPR records the transactions of National Daily Direct Hog Prior Day—Slaughtered Swine through the following categories of marketing arrangements (MAs):

- Negotiated purchases (MA1): Cash or spot market purchase of hogs by a packer from a producer when there is an agreement on base price and a delivery day not more than 14 days after the date on which the livestock are committed to the packer.
- Other market formula purchases (MA2): Purchase of hogs by a packer in which the pricing mechanism is a formula price based on any market other than the market for hogs, pork, or pork product. This includes formula purchases where the price formula is based on one or more futures and options contracts.
- Swine or pork market formula purchases (MA3): Purchase of hogs by a packer in which the pricing mechanism is a formula price based on a market for hogs, pork, or a pork product other than any formula purchase with floor, window, or ceiling price, or a futures options contract for hogs, pork, or pork product.
- Other purchase arrangements (MA4): Purchase of hogs by a packer that is not a negotiated purchase, hogs or pork market formula purchase, or other market formula

[3] The full text of the "en bloc amendment" can be found on the Senate Agriculture Committee Web site, http://www.agriculture.senate.gov/.

[4] MPR is available at http://mpr.datamart.ams.usda.gov/.

Table 1. Average Daily Transaction Volume (Heads) from Different Channels in Different Years

Variable	2001	2002	2003	2004	2005	2006	2007
Negotiated	61,040	51,640	47,546	40,301	40,518	35,463	32,641
Other formula	50,667	32,650	27,326	33,479	32,541	32,064	31,295
Swine formula	156,179	152,901	140,073	147,865	150,246	139,690	144,099
Other purchase	28,461	46,022	68,051	65,808	60,198	58,240	55,704
Packer owned	61,158	61,359	67,330	70,189	75,335	81,483	89,218
AMAs combined	296,465	292,932	302,780	317,341	318,320	311,477	320,316
Total	357,505	344,572	350,326	357,642	358,838	346,940	352,957

purchase and does not involve packer-owned swine. This would include long-term contract agreements, fixed price contracts, cost of production formulas, and formula purchases with a floor, window, or ceiling price.

- Packer owned (MA5): Hogs that a packer, including a subsidiary or affiliate of the packer, owns for at least 14 days immediately before slaughter.
- Packer sold (MA6): Hogs that are owned by a packer, including a subsidiary or affiliate of the packer, for more than 14 days immediately before sale for slaughter and sold for slaughter to another packer.

The data actually used are the daily total number of heads (barrows and gilts) and the associated average base price on the carcass weight basis for the period from August 20, 2001, to November 2, 2007, consisting of a total of 1,548 reporting days. During this period, the most widely used purchase method is swine or pork market formula (MA3) with 40.13% of hogs, followed by: the packer-owned (MA5) with a 20.01%; other purchase arrangement (MA4) with 15.70%; negotiated purchases (MA1) with 11.70%; other market formula (MA2) with 8.95%; and packer sold (MA6) with 3.50%.

For the purpose of this research, these subcategories were collapsed into two categories: *cash or spot market* category which includes only MA1, and the *alternative marketing arrangements* (AMAs) which includes MA2-MA5. The packer sold (MA6) category is excluded from AMAs because these hogs are not actually processed by packers but are rather sold as live hogs to other parties. A common feature of all AMAs is that when packers come to the spot market to buy live hogs, the number of hogs from AMAs is already predetermined and is therefore treated as packers' AMAs stocks. The principal reason for this is the fact that AMAs represent packers' long-term supply chain management decisions, where some of those contracts are written for up to five to ten years, whereas the decisions regarding how many hogs to buy on the spot market must be made on the daily basis. It is interesting to recognize (see table 1) that over the years, while the total number of hogs slaughtered per day remained roughly constant, the number of hogs transacted through the spot market has decreased from 61,040 per day in 2001, to 32,641 per day in 2007, whereas the number of hogs transacted through AMAs has increased from 296,465 to 320,316.

For the cash or spot market channel the daily prices and quantities are taken directly from the MPR data. For the AMAs channel, the daily quantity is set to be the sum of the quantities from the four subcategories, and the daily price is set to be the quantity-weighted average of the daily prices of these subcategories. Since the price for the packer-owned category (MA5) is not reported in the data, we set its price equal to the average transaction price for the packer sold (MA6) on the same transaction day. [5]

In addition to the national daily hog transactions (purchase) data, we also use several other data sources. Daily beef prices come from the MPR data series "National Daily Boxed Beef Cutout & Boxed Beef Cuts—Negotiated Sales—Afternoon," which reports daily total number of pounds and the associated average prices on the carcass weight basis for 58 different choice or select beef cuts. Since significant amount of data are missing for 26 cuts, we use the data for the remaining 32 cuts, which gives 1,548 reporting days and 50,560 observations.

[5] This seems to be a reasonable solution to the problem of missing MA5 data because it is based on a rather neutral assumption that packers sell hogs "at cost," i.e., at prices that would cover the cost of producing them at company-owned farms.

Table 2. Summary Statistics

Variable	Definition	Unit	Mean	Std. Dev.	Min	Max
P_{1t}	Cash price	Cents per pound[a]	59.63	10.83	26.92	81.56
Q_{1t}	Cash quan.	Heads	42,672.41	12,610.12	21,948	102,355
P_{2t}	AMAs price	Cents per pound[a]	59.70	9.38	34.42	78.54
Q_{2t}	AMAs quan.	Heads	309,151.7	44,357.45	139,529	588,135
W_t	Pork price	Cents per pound[a]	83.68	13.90	47	122
p_{bt}	Beef price	Cents per pound[a]	233.52	37.18	146.83	395.91
p_{ct}	Broiler price	Cents per pound[a]	67.36	9.78	45.23	87.3
p_{nt}	Corn price	Cents per bushel	237.36	56.65	163.5	412.5
p_{st}	Soy price	Cents per bushel	619.68	139.03	398.5	1040.63
p_{gt}	Gas price	Dollars per gallon	1.30	0.52	0.46	3.13

[a]On carcass weight basis. The sample size is 1,548.

Among these 50,560 observations, price data are still missing for 344 observations. For these observations, we set the number of pounds to 0, and then for each reporting day, we calculate a (pound) weighted average beef price.

Daily pork, broiler, corn, and soybeans prices are obtained from the Commodity Research Bureau.[6] Daily pork and broiler prices are the daily cash close prices for the Chicago Mercantile Exchange futures pork bellies (frozen, 12–14 pounds) contract and the futures broiler (Dressed 'A', 1–3/4 to 3–1/2 lb) contract. The daily corn and soybean price series are the daily cash close prices for the Chicago Board of Trade corn (No. 2 yellow) and soybeans (No. 1 yellow) futures contracts. Variable definitions, summary statistics and units of measurement for these variables are presented in table 2. Prices are not seasonally adjusted and are not adjusted for inflation.

Model

We model the industry as being comprised of N firms (packers) producing a homogenous output (pork) using a single homogenous material input (live hogs).[7] Following Schroeter (1988), Azzam (1997) and other economics literature on meat-packing, we assume a fixed proportion production technology. As a result, with appropriately chosen scale of prices,[8] the quantities of live animals input and the quantity of pork output can be represented by the same variable q^i, where $(i = 1, \ldots, N)$. Packers compete against each other by setting the output quantities. We assume that there are only two procurement channels: cash or spot market q_1 and the AMAs q_2.

Each time period t, given the stock of hogs q^i_{2t} from the AMAs, packer i decides on how many hogs to procure through the cash channel (q^i_{1t}) and then converts all the hogs to pork and sells the pork in the downstream market. Therefore, packer i's profit in period t is given by:

$$(1) \qquad \pi^i_t = \left[W_t\left(q^i_{1t} + q^i_{2t}\right) - P_{1t}q^i_{1t} - P_{2t}q^i_{2t} - C\left(q^i_{1t} + q^i_{2t}\right)\right]M$$

where W_t is the price of pork, $P_{1t}q^i_{1t}M$ is the payment to the live hog suppliers through the spot channel; $P_{2t}q^i_{2t}M$ is the payment to the live hog suppliers through the AMAs; $C(q^i_{1t} + q^i_{2t})$ is the packer i's production costs on a per pound of carcass weight basis; and M is the average pounds of pork in carcass weight of live hog.[9] Although q^i_{2t} is the packers' long-term decisions and is taken as given, the price P_{2t} will be determined in period t. This captures the fact that many marketing contracts use formula pricing where the contract price is linked to the current period spot price P_{1t}.[10]

To complete the model, we need to specify the cost function, the downstream inverse demand function for pork, the upstream inverse supply function for live hogs through the

[6] http://www.crbtrader.com/.

[7] We thus implicitly assume that other firms not considered in the model constitute the competitive fringe (price takers), both in the upstream live hogs market and the downstream pork market.

[8] In our case, the common unit for price variables (W_t, P_{1t}, and P_{2t}) is chosen to be cents per pound of carcass weight.

[9] We implicitly assume that: there are no quality differences between hogs from the spot market and those from the AMAs channel; they command the same price for pork; and they have identical processing costs. Vukina (2008) conducted a detailed analysis of the quality differences for hogs procured through MPR channels and found statistical differences in quality across channels, but these differences were economically insignificant to the point that they would all command the exact same quality premiums/discounts.

[10] An example of this type of formula pricing called "top-of-the-market clause" used in the beef sector is analyzed in Xia and Sexton (2004).

spot market, and the rule for determining the price of live hogs in the AMAs channel. Following Porter (1983), we specify the cost functions as:

$$(2)\quad C\left(q_{1t}^i + q_{2t}^i\right) = \left[\theta_1 + \frac{1}{2}\theta_2\left(q_{1t}^i + q_{2t}^i\right)\right]\left(q_{1t}^i + q_{2t}^i\right) + F$$

where the first part of C reflects the fact that the cost function is quadratic in quantities, i.e., $(\partial C)/(\partial q_{1t}^i) = (\partial C)/(\partial q_{2t}^i) = \theta_1 + \theta_2(q_{1t}^i + q_{2t}^i)$ and $(\partial^2 C)/(\partial(q_{1t}^i)^2) = (\partial^2 C)/(\partial(q_{2t}^i)^2) = \theta_2$, and F represents the fixed cost.[11]

The inverse demand function for pork is given by:

$$(3)\quad \log W_t = \gamma_0 + \eta \log(Q_t) + \gamma_1 \log p_{ct} + \gamma_2 \log p_{bt} + \boldsymbol{\gamma}_m \mathbf{D}_{mt} + \boldsymbol{\gamma}_y \mathbf{D}_{yt} + \gamma_t t + \gamma_{tsq} t^2 + e_{dt}$$

where $Q_t = \sum_{i=1}^{N}(q_{1t}^i + q_{2t}^i)$ is the total number of hogs that N packers procure through all channels; η represents the inverse demand elasticity (flexibility) for pork; and p_{ct} and p_{bt} are the prices of broiler chickens and beef, the two main substitutes for pork. To control for seasonal and macroeconomic effects as well as technological change and productivity shocks, the model includes a set of monthly dummies $\mathbf{D}_{mt}$ (the month January is omitted), a set of yearly dummies $\mathbf{D}_{yt}$ (the year 2007 is omitted), and a quadratic time trend. Finally, in spirit of Schroeter (1988), we assume that the error e_{dt} with the property that $E(e_{dt}) = 0$, follows an AR (1) process.

The inverse supply function for live hogs through the cash or spot market is given by:

$$(4)\quad \log P_{1t} = \delta_0 + \varepsilon \log(Q_{1t}) + \boldsymbol{\delta}_1 \log \mathbf{p}_{ft} + \boldsymbol{\delta}_m \mathbf{D}_{mt} + \boldsymbol{\delta}_y \mathbf{D}_{yt} + \delta_t t + \delta_{tsq} t^2 + e_{st}$$

where $Q_{1t} = \sum_{i=1}^{N} q_{1t}^i$ is the total number of hogs that N packers procure through the cash channel; ε is the inverse supply elasticity for live hogs through the cash channel; $\mathbf{p}_{ft}$ is a vector of prices of animals feed (corn and soybeans); and e_{1t} is an AR (1) shock with the property that $E(e_{1t}) = 0$.

Finally, the rule for determining the price of live hogs in the AMAs channel is modeled as:

$$(5)\quad \log P_{2t} = \lambda_0 + \mu \log(P_{1t}) + \boldsymbol{\lambda}_m \mathbf{D}_{mt} + \boldsymbol{\lambda}_y \mathbf{D}_{yt} + \lambda_t t + \lambda_{tsq} t^2 + e_{2t}$$

where e_{2t} is an AR (1) shock with the property that $E(e_{2t}) = 0$.

Given the existing AMAs stocks $q_{2t}^i (i = 1, \ldots, N)$, in every period packer i chooses q_{1t}^i to maximize its current period profit π_t^i. Using (1) and (2) the first order condition for profit maximization is as follows:

$$(6)\quad \frac{\partial W_t}{\partial Q_t}\frac{\partial Q_t}{\partial q_{1t}^i}\left(q_{1t}^i + q_{2t}^i\right) + W_t - \frac{\partial P_{1t}}{\partial Q_{1t}}\frac{\partial Q_{1t}}{\partial q_{1t}^i} q_{1t}^i - P_{1t} - \frac{\partial P_{2t}}{\partial P_{1t}}\frac{\partial P_{1t}}{\partial Q_{1t}}\frac{\partial Q_{1t}}{\partial q_{1t}^i} q_{2t}^i - \theta_1 - \theta_2\left(q_{1t}^i + q_{2t}^i\right) = 0$$

where $i = 1, \ldots, N$. From (3), (4), and (5), it follows that $(\partial W_t)/(\partial Q_t) = \eta(W_t)/(Q_t)$, $(\partial P_{1t})/(\partial Q_{1t}) = \varepsilon(P_{1t})/(Q_{1t})$, $(\partial P_{2t})/(\partial P_{1t}) = \mu(P_{2t})/(P_{1t})$, and $\phi_t^i = (\partial Q_t)/(\partial q_{1t}^i) = (\partial Q_{1t})/(\partial q_{1t}^i)$, since $Q_{2t} = \sum_{i=1}^{N} q_{2t}^i$ is taken as given. ϕ_t^i can be interpreted as packer i's perceived change of total market procurement of live hogs through the spot market (hence output), when its own procurement of live hogs through the spot market (hence output) changes. It is a measure of the market power packer i enjoys on the spot market for live hogs. If the packer is a price-taking firm, then $\phi_t^i = 0$, as he expects that changes in his own procurement level will leave the total market procurement of live hogs through the spot market unchanged. In another extreme when packer i is a monopolist, then $\phi_t^i = 1$, as there is a *one-to-one* correspondence between packer i's procurement and the total market procurement. In general $\phi_t^i > 0$ indicates that packer i enjoys some degree of market power.

Since we only have access to industry level data rather than firm level data, (6) cannot be used for estimation. Therefore, we need to

[11] An alternative specification often used in the literature (e.g., Schroeter 1988) is the generalized Leontief cost function, which specifies the cost as a function of the quantity and factor prices. We do not adopt that approach because we estimate the model using daily data. In generalized Leontief cost function, the input prices enter into the firms' first order conditions, and estimating such a model would require daily observations on input prices such as daily wage rates, etc., which is beyond the scope of this article.

derive the industry version of (6). To do so, we need to make the assumption that $\phi_t^i = \phi_t$ for all i, which is often made in the literature. With this assumption, we can sum (6) over the N firms and then divide both sides of the equation by N to get the first order condition for a representative packer:

$$(7) \quad \frac{\eta W_t \phi_t}{N} + W_t - P_{1t} - \frac{\varepsilon P_{1t}\phi_t}{N} - \frac{\mu P_{2t}\varepsilon}{N}\frac{Q_{2t}}{Q_{1t}}\phi_t - \theta_1 - \theta_2\frac{Q_t}{N} = 0.$$

Rearranging and appending the first order condition with an additive optimization AR (1) error term e_t with the property $E(e_t) = 0$, (7) can be rewritten as

$$(8) \quad \frac{\eta\phi_t}{N}W_t + W_t = P_{1t} + \frac{\varepsilon\phi_t}{N}P_{1t} + \frac{\mu\varepsilon\phi_t}{N}\frac{Q_{2t}}{Q_{1t}}P_{2t} + \theta_1 + \theta_2\frac{Q_t}{N} + e_t.$$

The term $(\eta\phi_t/N)W_t$ can be interpreted as a measure of packers' benefit in the downstream pork market due to its market power in the upstream spot market for live hogs. In addition the market power potentially benefits the packers in the upstream live hog markets in two ways. First, the term $(\varepsilon\phi_t/N)P_{1t}$ can be interpreted as the price markdown due to packers' market power on the spot market. The term $(\mu\varepsilon\phi_t/N)(Q_{2t}/Q_{1t})P_{2t}$ represents the price markdown in the AMAs channel due to the packers' market power as well as various formula pricing clauses in marketing contracts. If the representative packer does not enjoy any market power on the spot market, that is $\phi_t = 0$, then (8) reduces to the equality between the marginal benefit of converting additional live hogs into a pound of pork (W_t) and the marginal costs (the cost of live hogs P_{1t} plus the marginal production cost $\theta_1 + \theta_2(Q_t/N)$).

To test whether the use of AMAs is the source of packers' market power on the spot market, we model ϕ_t as:

$$(9) \quad \phi_t = \theta_3 + \theta_4 Q_{2t} + \theta_5 Q_{2t}^2 + \boldsymbol{\theta}_m \mathbf{D}_{mt} + \boldsymbol{\theta}_y \mathbf{D}_{yt} + \theta_t t + \theta_{tsq} t^2.$$

This specification approximates packers' conjecture in period t as a function of the AMAs stocks of live hogs. If indeed the use of the AMAs is the source of the market power on the spot market, then we should not reject the hypothesis that the term $\theta_4 Q_{2t} + \theta_5 Q_{2t}^2$ has no impact on ϕ_t.

Estimation and Results

Expressions (3), (4), (5), and (8) comprise a system of simultaneous equations. To estimate this system, we can either use a full information method, which estimates the entire system of equations at the same time, or a limited information method, which estimates each equation of the system separately. However, if a full information method is used, any specification error in any equation of the model will be propagated throughout the entire system. A limited information estimator, on the other hand, will confine a problem to the particular equation in which it appears (see Greene 2002). The use of a limited information estimator significantly reduces the computational burden as well. This can be seen from the fact that if one uses generalized method of moments (GMM), the moment conditions for equation (8) will be nonlinear in the parameters. Using full information maximum likelihood (FIML) approach (another full information estimator) will be computationally even more difficult because (8) is nonlinear in endogenous variables. On the other hand if we estimate equations separately, each will be a linear function of the parameters.

Demand for Pork

We first estimate the inverse demand function for pork equation (3). There are two issues that need to be addressed. First, the error term is assumed to follow an autocorrelation (AR) (1) process.[12] Second, the error term may also be heteroscedastic. Serial correlation and heteroscedasticity in the error term do not affect the consistency of the estimated coefficients, but failing to control for them would adversely affect inference. To obtain the correct standard errors of estimated coefficients in all regressions (regardless of whether they are GMM or OLS), we use the kernel-based heteroscedasticity and autocorrelation consistent standard error estimator proposed by Newey and West (1987). The kernel chosen here is the recommended Bartlett kernel, and the bandwidth

[12] We also estimated the equations assuming an AR(2), AR(3) or AR(4) error term; results are very similar.

Table 3. Estimation Results for the Inverse Demand for Pork

Variable	Estimate	t-stat	Variable	Estimate	t-stat
γ_0	38.8608	4.53	$\boldsymbol{\gamma}_m$		
γ_1	0.4366	2.13	Feb	−0.0641	−1.12
γ_2	0.1544	1.83	Mar	−0.0426	−0.50
η	−3.0481	−4.21	Apr	−0.1311	−1.07
$\boldsymbol{\gamma}_y$			May	−0.1998	−1.19
2002	1.4489	0.69	Jun	−0.2618	−1.30
2003	1.2195	0.73	Jul	−0.1990	−0.86
2004	0.9907	0.79	Aug	−0.2181	−0.85
2005	0.5047	0.60	Sep	−0.0797	−0.28
2006	0.1094	0.26	Oct	−0.0619	−0.20
γ_t	0.0017	1.00	Nov	−0.0915	−0.27
γ_{tsq}	$-2.53 * 10^{-7}$	−1.19	Dec	−0.1447	−0.39
Hansen's J	3.588		Anderson's LR	22.28	
			Number of Obs.	1,428	

parameter is set to two such that it is consistent with the AR (1) assumption for the error term.[13]

Second, the right-hand side output quantities $\log(Q_t)$ might be endogenous since equilibrium quantity is simultaneously determined with price. Therefore, we use the single-equation two-step optimal GMM estimation. To identify the model and conduct the estimation, we need instruments. Since this is a demand equation, supply shifters are usually good candidates. Since the finishing stage of hog production lasts 16–20 weeks, feed prices at the beginning of the grow-out period might be more relevant to farmers' decisions on how many hogs to produce than contemporaneous feed prices. In addition, the spot market hog supply in period t may be influenced by the average spot prices in the near past. For example, if farmers selling on the spot market see favorable prices today, they may decide to expedite the sale of their hogs to take advantage of the favorable market condition. With these insights, we use four instruments: $\log(p_{n(t-120)}), \log(p_{s(t-120)}), \log(P_{1(t-1)})$, and $\log(P_{1(t-2)})$, where $p_{n(t-120)}$ and $p_{s(t-120)}$ are the prices for corn and soybeans 120 days ago, and $\log(P_{1(t-1)})$ and $\log(P_{1(t-2)})$ are the average spot prices for live hogs one day and two days ago.

Table 3 presents the estimation results for the inverse demand for pork. Notice first that the sample size is reduced due to the use of lagged variables. Next, we examine the quality of instruments. The Hansen's J statistic is 3.59. The degree of freedom is 3 (the number of instruments minus the number of endogenous variables) and the critical value at 5% level for the χ^2 distribution with 3 degrees of freedom is 7.82. Hence, we cannot reject the joint null hypotheses that our model is correctly specified and the orthogonality conditions are satisfied. Table 3 also reports the Anderson canonical correlations likelihood-ratio (LR) statistic of 22.28. This is a test of whether the equation is identified, i.e., whether the excluded instruments are relevant. Under the null of under-identification or weak instruments, the statistic is distributed as χ^2 with degrees of freedom $L - K + 1$, where L is the number of instruments, and K is the number of endogenous variables. In our case, $L - K + 1 = 4$. The critical value at 5% level for the χ^2 distribution with 4 degrees of freedom is 9.49. Therefore, we reject the null hypothesis of under-identification or weak instruments at 5% level.

Turning now to the estimates, we see that almost all of the estimates have the expected signs. The own price elasticity (flexibility) is negative: as the pork price goes up, quantity demanded goes down. The cross-price elasticities for beef and chickens are both positive. As the prices for beef and chickens rise, the price for pork also goes up because they are substitutes. The daily inverse demand elasticity is −3.0481, implying a daily demand elasticity of −0.3281. Comparing our findings with other literature in the meat demand estimation[14] reveals that,

[13] Additional discussion of this method is available in Chapter 3 of Hayashi (2002). Estimation is conducted using the *ivreg2* command in Stata. Please see Baum, Schaffer, and Stillman (2003) for computational details.

[14] To the best of our knowledge, our elasticity is the first estimated daily demand elasticity for pork in the literature. However,

Table 4. Estimation Results for the Inverse Supply for Spot Market Hogs

Variable	Estimate	*t*-stat	Variable	Estimate	*t*-stat
δ_0	−1.2176	−0.74	$\boldsymbol{\delta}_m$		
ϵ	0.6440	3.15	Feb	0.1277	3.67
$\boldsymbol{\delta}_1$			Mar	0.1939	4.10
$\log(p_{n(t-120)})$	0.1950	2.47	Apr	0.2393	3.51
$\log(p_{s(t-120)})$	0.0254	0.28	May	0.4331	4.61
$\boldsymbol{\delta}_y$			Jun	0.4904	4.39
2002	−3.1800	−2.46	Jul	0.5344	3.91
2003	−2.5386	−2.44	Aug	0.5068	3.33
2004	−1.6607	−2.16	Sep	0.4306	2.54
2005	−1.1326	−2.14	Oct	0.4560	2.39
2006	−0.5645	−2.14	Nov	0.4857	2.27
δ_t	−0.0016	−1.69	Dec	0.5484	2.32
δ_{tsq}	$-2.83 * 10^{-7}$	−2.07	Number of obs	1,428	
Anderson's *LR*	15.34		Hansen's *J*	0.79	

taking into consideration the frequency of data used, our results are very similar to what other studies had found.

Supply of Live Hogs on the Spot Market

In the case of the inverse supply function for live hogs through the spot channel (4), we first need to decide how to measure $\log(\mathbf{p}_{ft})$, i.e., the input prices for production factors. As discussed before, the feed prices at the beginning of the grow-out period may be more relevant for making decisions about how many hogs to grow than contemporaneous prices, hence we use $\log(p_{n(t-120)})$ and $\log(p_{s(t-120)})$.

Similar to the demand estimation, in estimating the supply function, we are also faced with the problem of equilibrium quantities being simultaneously determined with prices. To address the endogeneity problem, we use two instruments: the total number of hogs procured through the AMA channels lagged one and two periods, $\log(Q_{2(t-1)})$ and $\log(Q_{2(t-2)})$. These past periods' procurement quantities are unlikely to be correlated with the current period error term in the inverse spot market supply equation. Also, they are likely to be correlated with the potentially endogenous variable Q_{1t}. This is because firms make decisions on Q_{1t} based on Q_{2t}, which in turn are likely to be correlated with the firms' decisions on $Q_{2(t-1)}$ and $Q_{2(t-2)}$. Using these instruments, we estimate the inverse supply equation with GMM.

Table 4 presents the estimation results for the inverse supply function for live hogs through the cash channel. Again, before discussing the estimates, we first examine the quality of the instruments. The Hansen's *J* statistic is 0.79. The degree of freedom here is 1, and the critical value at 5% level for χ^2 distribution with 1 degree of freedom is 3.84. Hence, we cannot reject the joint null hypotheses that our model is correctly specified and the orthogonality conditions are satisfied. We also report the Anderson canonical correlations LR statistic of 15.34. Under the null of under-identification or weak instruments, the statistic is distributed as χ^2 with 2 degrees of freedom in this case. The critical value at 5% level for χ^2 distribution with 2 degrees of freedom is 7.38. Therefore, we reject the null hypothesis of under-identification or weak instruments at 5% level.

Turning now to coefficient estimates, we first see that the own price inverse supply elasticity is positive and significant ($\eta = 0.644$), which means that the implied daily supply elasticity for live hogs is 1.55.[15] The results seem to be indicating that in the very short-run, the farmers

pork demand elasticities at longer time frequencies are available. USDA-ERS maintains a database of demand elasticities from the literature at http://www.ers.usda.gov/Data/Elasticities/. The average of the 18 yearly own price pork elasticity records is −0.8577, with two outliers: −0.17 and −3.257. The average for the remaining 16 cross-section household level elasticity measures is −0.7749 and the standard deviation is 0.1658. Also, using monthly data, Lusk et. al. (2001) report the demand elasticity of −0.471.

[15] Again, it appears that our daily spot market supply elasticity for live hogs is the only such estimate in the literature. Dean and Heady (1958) report that the yearly elasticity for the number of sows farrowing (an approximation for live hog supply) is 0.60 (standard error 0.09) for the period 1938–1956. Hayenga and Hacklander (1970) found negative monthly supply elasticity of about −1 for the 1963–1968 period. They argue their negative supply elasticity comes from the fact that farmers believe there is a strong trend in hog price and will continue to increase production if this period's price is higher than last period's. As a result, farmers rationally delay the supply of hogs. Interestingly enough, they simultaneously found that the monthly supply elasticity for fed cattle is around 0.91.

actually try to take advantage of daily price fluctuations on the spot market, by advancing or delaying the sale of live hogs, something that would be impossible in the intermediate or longer run. Delaying or advancing the sales of finishing hogs by several weeks, let alone months, would be nearly impossible to accomplish. Finally, we see that higher corn price leads to higher price for live hogs, but the soybean price has an insignificant effect. This could be the result of the co-movement of these two prices, which causes the marginal effect of one variable to diminish after controlling for the other.

Pricing of Live Hogs in AMAs

Estimating the equation determining the price of live hogs in the AMAs channel (5) is reasonably straightforward. Due to various formula pricing clauses used in the marketing contracts, P_{1t} is an exogenous determinant of P_{2t}. As a result, there are no endogenous variables on the right-hand side of equation (5), hence this equation is estimated using standard OLS. Estimation results are presented in table 5. As expected, as a consequence of the formula pricing clauses in marketing contracts, the captive supply price is closely related to the spot price. A 1% increase in the cash price corresponds to a 0.78% increase in the captive supply price. The model has almost a perfect fit.

Packers' First Order Conditions

Finally, we estimate equation (8). Inserting (9) into (8) and rearranging gives:

$$
\begin{aligned}
(10)\quad & W_t - P_{1t} \\
&= \theta_1 + \theta_2 \frac{Q_t}{N} \\
&\quad + \theta_3 \left[\frac{\mu\varepsilon}{N} \frac{Q_{2t}}{Q_{1t}} P_{2t} + \frac{\varepsilon}{N} P_{1t} - \frac{\eta}{N} W_t \right] \\
&\quad + \theta_4 \left[\frac{\mu\varepsilon}{N} \frac{Q_{2t}}{Q_{1t}} P_{2t} + \frac{\varepsilon}{N} P_{1t} - \frac{\eta}{N} W_t \right] Q_{2t} \\
&\quad + \theta_5 \left[\frac{\mu\varepsilon}{N} \frac{Q_{2t}}{Q_{1t}} P_{2t} + \frac{\varepsilon}{N} P_{1t} - \frac{\eta}{N} W_t \right] Q_{2t}^2 \\
&\quad + \boldsymbol{\theta}_m \left[\frac{\mu\varepsilon}{N} \frac{Q_{2t}}{Q_{1t}} P_{2t} + \frac{\varepsilon}{N} P_{1t} - \frac{\eta}{N} W_t \right] \mathbf{D}_{mt} \\
&\quad + \boldsymbol{\theta}_y \left[\frac{\mu\varepsilon}{N} \frac{Q_{2t}}{Q_{1t}} P_{2t} + \frac{\varepsilon}{N} P_{1t} - \frac{\eta}{N} W_t \right] \mathbf{D}_{yt} \\
&\quad + \theta_t \left[\frac{\mu\varepsilon}{N} \frac{Q_{2t}}{Q_{1t}} P_{2t} + \frac{\varepsilon}{N} P_{1t} - \frac{\eta}{N} W_t \right] t \\
&\quad + \theta_{tsq} \left[\frac{\mu\varepsilon}{N} \frac{Q_{2t}}{Q_{1t}} P_{2t} + \frac{\varepsilon}{N} P_{1t} - \frac{\eta}{N} W_t \right] t^2 \\
&\quad + e_t .
\end{aligned}
$$

As is written, equation (10) is a nonlinear function of the structural parameters $\theta_1, \ldots, \theta_5, \boldsymbol{\theta}_m, \boldsymbol{\theta}_y, \theta_t, \theta_{tsq}, \mu, \varepsilon$, and η. However, with μ, ε, and η estimated from the previous three equations, equation (10) becomes a linear function of the remaining structural parameters $\theta_1, \ldots, \theta_5, \boldsymbol{\theta}_m, \boldsymbol{\theta}_y, \theta_t, \theta_{tsq}$. This feature makes the computation a lot easier, and as mentioned before, is another advantage of the limited information estimator. Also, notice that due to the endogenous variable Q_{1t}, all of the terms except

Table 5. Estimation Results for Price Determination of Captive Supplies

Variable	Estimate	*t*-stat	Variable	Estimate	*t*-stat
λ_0	0.8740	8.88	$\boldsymbol{\lambda}_m$		
μ	0.7835	96.57	Feb	0.0030	1.44
$\boldsymbol{\lambda}_y$			Mar	0.0039	1.33
2001	−0.0022	−0.02	Apr	0.0040	0.99
2002	−0.0224	−0.30	May	0.0145	2.53
2003	−0.0111	−0.18	Jun	0.0173	2.47
2004	0.0017	0.04	Jul	0.0195	2.36
2005	−0.0001	$0.37 * 10^{-2}$	Aug	0.0181	1.93
2006	−0.0165	−1.10	Sep	0.0115	1.04
λ_t	$2.25 * 10^{-5}$	0.37	Oct	0.0031	0.27
λ_{tsq}	$-5.18 * 10^{-9}$	−0.85	Nov	−0.0003	−0.02
			Dec	−0.0021	−0.15
Adjusted R^2	0.9954		Number of obs.	1,548	

the constant term on the right-hand side of equation (10) are endogenous. To identify and estimate parameters $\theta_1, \ldots, \theta_5, \boldsymbol{\theta}_m, \boldsymbol{\theta}_y, \theta_t$, and θ_{tsq}, we need at least 24 or more instruments in the instrument vector Z_t. We use the constant, $Q_{2t}, Q_{2t}^2, \mathbf{D}_{mt}, \mathbf{D}_{yt}, t, t^2, t^2\ Q_{2t}$, $t^2 Q_{2t}^2, Q_{2(t-1)}, Q_{2(t-2)}, Q_{2(t-3)}$, and $Q_{2(t-4)}$, a total of 28 instruments. Variables like $\mathbf{D}_{mt}$ are good instruments, as they are uncorrelated with e_t but are correlated with endogenous variables $[(\mu\varepsilon/N)(Q_{2t}/Q_{1t})P_{2t} + (\varepsilon/N)P_{1t} - (\eta/N)W_t]\ \mathbf{D}_{mt}$ by construction. Lagged values of Q_{2t}, like $Q_{2(t-1)}$, are also good instruments, as they are packers' long-run decisions and hence are uncorrelated with the error term e_t and correlated with endogenous variables, like $[(\mu\varepsilon/N)(Q_{2t}/Q_{1t})P_{2t} + (\varepsilon/N)P_{1t} - (\eta/N)W_t]$, through correlation between Q_{2t} and $Q_{2(t-1)}$. We will also conduct formal statistical tests to examine the quality of the instruments. We also tried several other sets of instruments, and the results remain qualitatively the same.

Another issue we need to address here is the choice of N in the estimation. In our model, N is the number of packers in the industry that enjoy some degree of market power. According to a recent report by Vukina et al. (2007), among eighty-five packers that were surveyed, fifteen purchased about 76% of the total number of live hogs in 2004. Therefore, $N = 15$ seems to be a reasonable choice.

With η, ε, and μ estimated from the previous three regressions, we can now compute the regressors on the right-hand side of equation (10). This enables us to estimate the market power parameters using the single equation two-step optimal GMM. Since this is a two-stage estimation as estimates of η, ε and μ from the first stage regressions are used to construct the regressors in the second stage, the variance of the first stage parameter estimates need to be taken into account to obtain correct standard errors for the second stage estimates. This has been accomplished by a simulation procedure. For each simulation, we draw a set of values for η, ε, and μ from their estimated distributions in the first stage regressions. For example, table 3 reports that the estimate for η is -3.0481 with a t stat -4.21, implying the standard error of 0.7236. Therefore, for each simulation we draw η from a normal distribution with mean -3.0481 and standard deviation 0.7236. We repeat this procedure 250 times and obtain 250 estimates for each coefficient and test statistic in the second stage. The reported estimates for each coefficient and test statistic are the means of the 250 estimates and test statistics. The standard errors for these estimates and test statistics are calculated using the standard deviations of the 250 estimates and test statistics. The reported t-stats are simply the estimates and test statistics divided by their standard errors. Table 6 summarizes the estimation results.

Before discussing the estimates, we first examine the quality of the instruments. The Hansen's J statistic is 3.2398 with a t-statistic of 9.44 (implying a standard error of 0.3432). The degree of freedom is 4, and the critical value at 5% level for the χ^2 distribution with 4 degrees of freedom is 9.49. Hence, we cannot reject the joint null hypotheses that our model is correctly specified and the orthogonality

Table 6. Cost Function and Market Power Estimation Results

Variable	Estimate	t-stat	Variable	Estimate	t-stat
θ_1	6.0085	1.35	$\boldsymbol{\theta}_m$		
θ_2	0.0003	6.17	Feb	0.0295	4.45
θ_3	1.2975	2.75	Mar	0.2015	4.51
θ_4	$2.58 * 10^{-7}$	0.77	Apr	0.1705	4.37
θ_5	$-1.30 * 10^{-12}$	−3.27	May	0.1253	4.32
$\boldsymbol{\theta}_y$			Jun	0.0259	1.52
2001	−1.3802	−3.66	Jul	0.2394	4.42
2002	−1.0596	−3.58	Aug	0.1028	3.72
2003	−0.8056	−3.36	Sep	0.1073	3.54
2004	−0.9598	−3.68	Oct	0.1316	3.52
2005	−1.0884	−3.94	Nov	0.2378	3.80
2006	−0.6856	−4.01	Dec	0.3074	3.88
θ_t	0.0007	4.55			
θ_{tsq}	$-9.51 * 10^{-7}$	−4.20	Number of obs.	1,544	
Hansen's J	3.2398	9.44	Anderson's LR	51.1814	6.95

Table 7. Quantifying the Magnitude of Market Power

Variable	Estimate	t-stat
Average $W_t - P_{1t}$	24.05	NA
Average $\theta_1 + \theta_2 \frac{Q_t}{N}$	13.9720	4.40
Average $\frac{\eta\phi_t}{N} W_t$	−5.6031	−2.08
Average $\frac{\varepsilon\phi_t}{N} P_{1t}$	0.6450	5.29
Average $\frac{\mu\varepsilon\phi_t}{N} \frac{Q_{2t}}{Q_{1t}} P_{2t}$	3.8160	5.20
Average ϕ_t	0.3198	2.03
Average $\theta_4 Q_{2t} + \theta_5 Q_{2t}^2$	−0.0468	−0.55

conditions are satisfied. Table 6 also reports Anderson's canonical correlations LR statistic at 51.18 with a t-statistic of 6.95 (implying a standard error of 7.36). Under the null of under-identification or weak instruments, the statistic is distributed χ^2 with 5 degrees of freedom. The critical value at 5% level for the χ^2 distribution with 5 degrees of freedom is 11.07. Therefore, we reject the null hypothesis of under-identification or weak instruments at 5% level.

Turning now to parameter estimates, we first see that the marginal cost function has an insignificant constant θ_1 and a positive and significant slope θ_2/N. From table 2, we see that the average slaughter for a representative packer is around 23,455 ([42672.41 + 309151.7]/15) hogs per day; hence, the average marginal cost turns out to be 13.97 cents per pound of pork produced, which we report in table 7.

Second, relying on the definition of the conjectural variation parameter ϕ_t as an indicator of packers' market power on the spot market, we see that the estimate of θ_4 is positive and insignificant, and the estimate of θ_5 is negative and significant, indicating that packers' market power on the spot market increases with the total AMAs stock of live hogs but at a decreasing rate. When the AMAs stock of live hogs increases, the firms' needs to procure live hogs from the spot market become less urgent, and hence, the firm is in a better position to negotiate with farmers a more favorable purchase price. Table 7 reports that the average market power measure ϕ_t over the sample period is 0.3198 with a t-statistic of 2.03. The part of the market power that is attributed to the AMAs stock $\theta_4 Q_{2t} + \theta_5 Q_{2t}^2$ has an average of −0.0468 with a t-statistic of −0.55. This indicates the presence of statistically significant market power on the spot market for live hogs whose source, however, cannot be tied to the firms' AMAs stocks. Therefore, the origin of that market power on the spot market for live hogs is likely to be related to the traditional oligopsony (industry concentration) issues.

Finally, we also see that most of the coefficients for monthly dummies, yearly dummies, and trend variables in the market power function are statistically significant at the 1% level, indicating packers' market power on the spot market varies over different seasons and years.

With the obtained parameter estimates, we can now decompose equation (8) into the marginal cost part and the market power part. Over the sample period the average price spread between the price of live hogs the farmers receive and the price of pork that packers receive is about 24.05 cents per pound of pork. The results in table 7 show that 13.97 cents out of the price spread is used to cover the processing costs, and the rest can be attributed to the packers' market power.[16] A representative packer's markup in the downstream pork market due to its market power in the upstream spot market for live hogs $(\eta\phi_t/N)W_t$ is about 5.6 cents. The price markdown due to the market power on the spot market itself $(\varepsilon\phi_t/N)P_{1t}$ is about 0.65 cents. Finally, the price markdown in the AMAs channel due to the market power directly and through various formula pricing clauses in the marketing contracts $(\mu\varepsilon\phi_t/N)(Q_{2t}/Q_{1t})P_{2t}$ indirectly is about 3.82 cents. Therefore, the major benefit of packers' market power is realized through the price distortion on the pork market and the link between the spot market price and the AMAs prices through various pricing formulas. This first is due to the fact that the estimated daily demand for pork is pretty inelastic, and the second is due to the fact that the number of live hogs transacted through AMAs is about seven-times the cash market volume. Because the average pork price W_t is 83.68 cents per pound and the average live hogs spot market price is 59.63 cents (see table 2), the percent markup in the downstream market is around 6.7%, and the percent markdown in the upstream spot market is around 1.1%.[17]

[16] This estimate is very close to MacDonald and Ollinger (2000), who report the processing cost for a plant with a yearly capacity of four million hogs around 10.28 cents per pound of liveweight in 1992. In our data, the average firm yearly capacity is about six million heads, and our estimate is based on the carcass weight. Since the average yield for hogs is around 75%, it implies a processing cost around 10.49 cents per pound of liveweight.

[17] Our results fall in the range of markup and markdown estimates found elsewhere in the literature. For example, analyzing beef packing industry in 1951–1983 period with yearly data, Shroeter (1988) reports the markups in downstream market in the range from 0.0268 to 0.0791, and the markdowns in upstream market in the range from 0.0084 to 0.0247.

Table 8. Robustness Analysis Regarding the Number of Firms

Variable	Estimate	*t*-stat	Estimate	*t*-stat
Parameters/Quantities of Interest	$N = 4$		$N = 8$	
θ_1	6.0085	1.35	6.0085	1.35
θ_2	0.0001	6.17	0.0002	6.17
θ_3	0.3460	2.75	0.6920	2.75
θ_4	$6.88 * 10^{-8}$	0.77	$1.38 * 10^{-7}$	0.77
θ_5	$-3.46 * 10^{-13}$	−3.27	$-6.92 * 10^{-13}$	−3.27
Hansen's J	3.2398	9.44	3.2398	9.44
Anderson's LR	51.1814	6.95	51.1814	6.95
Average $\theta_1 + \theta_2 \frac{Q_t}{N}$	13.9720	4.40	13.9720	4.40
Average $\frac{\eta\phi_t}{N} W_t$	−5.6031	−2.08	−5.6031	−2.08
Average $\frac{\varepsilon\phi_t}{N} P_{1t}$	0.6450	5.29	0.6450	5.29
Average $\frac{\mu\varepsilon\phi_t}{N} \frac{Q_{2t}}{Q_{1t}} P_{2t}$	3.8160	5.20	3.8160	5.20
Average ϕ_t	0.0853	2.03	0.1706	2.03
Average $\theta_4 Q_{2t} + \theta_5 Q_{2t}^2$	−0.0125	−0.55	−0.0250	−0.55

Robustness

As seen in the previous section, for the purpose of estimating the first order conditions we chose the number of packers in the industry that enjoy some market power to $N = 15$. As explained in the text, our choice is based on the survey results from Vukina et al. (2007). However, the most recent GIPSA statistical report for hog slaughter (2005 data) reports a four-firm concentration ratio of 64%, and an eight-firm concentration ratio of 88%.[18] In light of some differences regarding the industry concentration estimates, it seems worthwhile to examine the robustness of the above results to alternative choices of N. To accomplish this task, we repeat the entire estimation procedure for $N = 4$ and $N = 8$.

Compared with results in tables 6 and 7, the new results in table 8 show that using alternative values of N leave the estimates of several parameters and quantities of interest intact. Also, all t-statistics remain the same as before. The reason behind this can be easily seen by a closer examination of the estimating equation (10). For example, it is clear that the variation in Q_t identifies (and hence pins down) θ_2/N but not θ_2 and N separately. Therefore, when a smaller N is used, the resulting θ_2 is smaller, leaving θ_2/N and hence the quantity of interest $\theta_1 + \theta_2(Q_t/N)$ unchanged. The same reasoning applies to θs in other terms as well. As a result, the estimates for ϕ_t and $\theta_4 Q_{2t} + \theta_5 Q_{2t}^2$ become smaller, but market power measures $(\eta\phi_t/N)W_t$, $(\varepsilon\phi_t/N)P_{1t}$, and $(\mu\varepsilon\phi_t/N)(Q_{2t}/Q_{1t})P_{2t}$ all intact. On the other hand, the standard errors of the estimates are determined by the variation in the data used for estimation. Since using alternative values for N does not change the variation in the observed data, it has no impact on the significance levels of the estimated coefficients and quantities of interest. These results lead us to the conclusion that the choice of N has no impact on our main result—that is, the source of the statistically significant market power on the spot market for live hogs cannot be tied to the firms' AMAs stocks.

Conclusion

This paper contributes significantly to the fairly large literature on the estimation of market power in the meat packing industries. Two features clearly distinguish this work from the rest of the literature in this field. First, for the first time the model explicitly tests whether the use of AMAs is a source of market power that packers enjoy on the spot market. Second, this paper deals with the issue of market power in the live hogs and pork markets, whereas the great majority of other work has been addressing the issue of captive supplies and the question of market power in the cattle and beef markets.

For the purposes of testing whether market power on the spot market exists and whether the source of that market power could be related to the use of AMAs in procurement of

[18] We are thankful to an anonymous referee for bringing these estimates to our attention. The said report is available at http://archive.gipsa.usda.gov/pubs/2005_stat_report.pdf.

live hogs, we estimated a conjectural variation model using the MPR data. In this model, we specified the packers' conjectures of the change in total market procurement of live hogs through the spot market with respect to their own changes in procurement as explicit functions of their AMAs supply stocks. We found a statistically significant presence of market power in the procurement of live hogs on the spot market. However, the source of that market power cannot be narrowed down to the industry's AMAs stocks but is likely to be related to classical oligopsony (concentration) issues.

What are the implications of the obtained results for future industry structure and conduct? Historically, it has been well-documented that spot markets were becoming thinner and that the importance of AMAs has grown over time. However, this trend seems to have stopped, and the interviews with industry participants as well as the industry survey results indicate that the industry is not expecting any major changes in the composition of procurement methods for live hogs in the near future (see, Vukina et al., 2007). Given the fact that the current level of AMAs utilization does not seem to be the source of packers' market power on the spot market, it is reasonable to expect no significant deterioration in the industry competitiveness due to further reduction in volume of the spot market transactions. The problem seems to be coming from the ever-increasing industry concentration and not from the increasing use of AMAs. In markets where there is only one or few buyers, the transacted volume could be large, and the competitiveness could still be stifled. On the other hand, in markets where the number of buyers is large, the volume could be substantially smaller, yet the industry conduct will still remain competitive.

[Received May 2007; accepted May 2008.]

References

Appelbaum, E. 1982. "The Estimation of the Degree of Oligopoly Power." *Journal of Econometrics* 19:287–99.

Azzam, A.M. 1997. "Measuring Market Power and Cost-Efficiency Effects of Industrial Concentration." *Journal of Industrial Economics* 45:377–86.

——. 1998. "Captive Supplies, Market Conduct and the Open-Market Price." *American Journal of Agricultural Economics* 80:76–83.

Azzam, A.M., and D.G. Anderson. 1996. "Assessing Competition in Meatpacking: Economic History, Theory and Evidence." Prepared for the USDA Grain Inspection, Packers and Stockyards Administration, Report GIPSA-RR 96-6, Washington DC.

Baum, C.F., M.E. Schaffer, and S. Stillman. 2003. "Instrumental Variables and GMM: Estimation and Testing." *Stata Journal* 3:1–31.

Bresnahan, T. 1989. "Empirical Studies of Industries with Market Power." In R. Schmalensee and R. Willig, eds. *Handbook of Industrial Organization*, Vol. 2, pp. 1011–57. San Diego CA: Elsevier Science Publishers.

Crespi, J.M., and R.J. Sexton. 2004. "Bidding for Cattle in the Texas Panhandle." *American Journal of Agricultural Economics* 86:660–74.

——. 2005. "A Multinomial Logit Framework to Estimate Bid Shading in Procurement Auctions: Application to Cattle Sales in the Texas Panhandle." *Review of Industrial Organization* 27:253–78.

Dean, G.W., and E.O. Heady. 1958. "Changes in Supply Response and Elasticity for Hogs." *Journal of Farm Economics* 40:845–60.

Elam, E. 1992. "Cash Forward Contracting vs. Hedging of Fed Cattle, and the Impact of Cash Contracting on Cash Prices." *Journal of Agricultural and Resource Economics* 17:205–17.

Greene, W.H. 2002. *Econometric Analysis*. Upper Saddle River, NJ: Pearson Education, Inc.

Grimes, G., R. Plain, and S. Meyer. 2004. "U.S. Hog Marketing Contract Study," University of Missouri and Paragon Economics, Department of Agricultural Economics Working Paper No. AEWP 2004-07. Accessed August 7, 2008 at: www.agebb.missouri.edu/mkt/vertstud04.htm.

Hayashi, F. 2002. *Econometrics*. Princeton, NJ: Princeton University Press.

Hayenga, M., and D. Hacklander. 1970. "Monthly Supply-Demand Relationships for Fed Cattle and Hogs." *American Journal of Agricultural Economics* 52:535–44.

Hayenga, M., and D. O'Brien. 1992. "Packer Competition, Forward Contracting Price Impacts, and the Relevant Market for Fed Cattle." In W. Purcell, ed. *Pricing and Coordination in Consolidated Livestock Markets: Captive Supplies, Market Power, and IRS Hedging Policy*, pp. 45–66. Blacksburg, VA: Virginia Tech University, Research Institute on Livestock Pricing.

Lusk, J.L., T.L. Marsh, T.C. Schroeder, and J.A. Fox. 2001. "Wholesale Demand for USDA Quality Graded Boxed Beef and Effects of Seasonality." *Journal of Agricultural and Resource Economics* 26:91–106.

MacDonald, J.M., and M.E. Ollinger. 2000. "Scale Economies and Consolidation in Hog Slaughter." *American Journal of Agricultural Economics* 82:334–46.

Morrison Paul, C.J. 2001. "Cost Economies and Market Power: The Case of the U.S. Meat Packing Industry." *Review of Economics and Statistics* 83:531–40.

Murray, B.C. 1995. "Measuring Oligopsony Power with Shadow Prices: U.S. Markets for Pulpwood and Sawlogs." *Review of Economics and Statistics* 77:486–98.

Newey, W.K., and K.D. West. 1987. "A Simple Positive Semi-definite Heteroscedasticity and Autocorrelation Consistent Covariance Matrix." *Econometrica* 55:703–08.

Porter, R. 1983. "A Study of Cartel Stability: The Joint Executive Committee, 1880–1886." *Bell Journal of Economics* 14:301–14.

Schroeder, T., R. Jones, J. Mintert, and A. Barkley. 1993. "The Impact of Forward Contracting on Fed Cattle Transaction Prices." *Review of Agricultural Economics* 15:325–37.

Schroeter, J.R. 1988. "Estimating the Degree of Market Power in the Beef Packing Industry." *Review of Economics and Statistics* 70:158–62.

Schroeter, J.R., and A.M. Azzam. 2003. "Captive Supplies and the Spot Market Price of Fed Cattle: The Plant-Level Relationship." *Agribusiness* 19:489–504.

U.S. Department of Agriculture, Grain Inspection, Packers and Stockyards Administration (USDA-GIPSA) 2001. "Packers and Stockyards Statistical Report, 2001." Accessed August 7, 2008 at: http://archive.gipsa.usda.gov/pubs/stat01/part2_01.pdf.

U.S. Department of Agriculture, Agricultural Marketing Service (USDA-AMS) 1996. *Concentration in Agriculture: A Report of the Advisory Committee on Agricultural Concentration*. Washington DC.

Vukina, T. 2008. "Quality Differences and Risk Shifting Associated with Alternative Marketing Arrangements in the Swine Industry." *Journal of Food Distribution Research*, forthcoming.

Vukina, T., M.K. Muth, N.E. Piggott, C. Shin, M.K. Wohlgenant, X. Zheng, S.C. Cates, M.C. Coglaiti, S.A. Karns, J. Lawrence, J.L. Taylor, and C.L. Viator. 2007. "GIPSA Livestock and Meat Marketing Study, Volume 4. Hog and Pork Industries." Report prepared for USDA, Grain Inspection, Packers and Stockyards Administration, Washington DC.

Xia, T., and R.J. Sexton. 2004. "The Competitive Implications of Top-of-the-Market and Related Contract-Pricing Clauses." *American Journal of Agricultural Economics* 86:124–38.