Effects of Concentration On Prices Paid for Cattle

by

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PREFACE

Congress included $500,000 in the U.S. Department of Agriculture's (USDA) Packers and Stockyards Administration (now Grain Inspection, Packers and Stockyards Administration (GIPSA)) 1992 fiscal-year appropriation to conduct a study of concentration in the red meat packing industry. GIPSA solicited public comments on how to conduct the study and formed an interagency working group to advise the Agency on the study. Based on the public input and comments of the working group, GIPSA selected seven projects and contracted with university researchers for six of them.

The findings of the study are summarized in Packers and Stockyards Programs, GIPSA, USDA, *Concentration in the Red Meat Packing Industry*, February 1996. The technical reports of the contractors are published as a series of Grain Inspection, Packers and Stockyards Administration Research Reports (GIPSA-RR). The technical reports of the contractors are:

GIPSA-RR 96-1	Marvin L. Hayenga, Stephen R. Koontz, and Ted C. Schroeder, *Definition of Regional Cattle Procurement Markets*.
GIPSA-RR 96-2	Slaughter Cattle Procurement and Pricing Team, Texas A&M Agricultural Market Research Center, *Price Determination in Slaughter Cattle Procurement*.
GIPSA-RR 96-3	Clement E. Ward, Ted C. Schroeder, Andrew P. Barkley, and Stephen R. Koontz, *Role of Captive Supplies in Beef Packing*.
GIPSA-RR 96-4	S. Murthy Kambhampaty, Paul Driscoll, Wayne D. Purcell, and Everett D. Peterson, *Effects of Concentration on Prices Paid for Cattle*.
GIPSA-RR 96-5	Marvin L. Hayenga, V.J. Rhodes, Glenn A. Grimes, and John D. Lawrence, *Vertical Coordination in Hog Production*.
GIPSA-RR 96-6	Azzeddine Azzam and Dale Anderson, *Assessing Competition in Meatpacking: Economic History, Theory, and Evidence*. This project reviewed relevant research literature.

The seventh project analyzed hog procurement in the eastern Corn Belt, and was conducted by the Economic Research Service, U.S. Department of Agriculture. The findings of this project are included in the summary report on the study referenced above and are not published in a separate technical report.

This report is based on work performed under contract for GIPSA, USDA. The views expressed in this report are those of the authors and are not necessarily those of GIPSA or USDA.

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ON PRICES PAID FOR CATTLE

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1. Introduction

Over the past 15 years, the number of firms participating in the beef packing industry has dwindled and now 4 firms slaughter as much as 80 percent of the fed steers and heifers in the United States. Accompanying the concentration in this industry have been allegations that the remaining large firms engage in noncompetitive behavior and, in particular, manipulate cattle markets to the detriment of cow-calf producers and feedlot operators.

In 1990, the General Accounting Office (GAO) released a review of studies on this issue entitled *Beef Industry: Packer Market Concentration and Cattle Prices*. The GAO declined to draw conclusions about the relationship between the level of concentration and prices paid for cattle because of the methods used in particular studies or the time period studied (most studies used data collected prior to the 1980s). In October 1991, the GAO cited the need to examine the ways in which the packing industry was being regulated and analyzed. It was in this environment that, in 1993, Congress asked the Packers and Stockyards Administration, now Packers and Stockyards Programs, Grain Inspection, Packers and Stockyards Administration (GIPSA) of USDA, to conduct a study of the impacts of market concentration in the beef packing industry. The following is a report on the effect of concentration of prices paid for cattle, one of several specific research projects commissioned by GIPSA.

Econometric models testing hypotheses of noncompetitive conduct have been proposed by Applebaum (1979, 1982), and by Gollop and Roberts (1979), and have since been applied to the beef processing industry (Schroeter 1988; Azzam and Schroeter 1991; Azzam and Pagoulatos 1990). Applebaum (1979) proposes a model seeking evidence of *monopoly* pricing: a profit-maximizing monopolistic firm chooses output so that marginal revenue equals marginal cost of production, whereas a competitive firm maximizes profits when marginal cost equals an output price that the firm cannot influence. Applebaum's model is used to derive a supply relation or profit condition which provides an expression for the monopolist's markup of output price over marginal cost. The hypothesis that the firm does not influence output price is then tested by testing the hypothesis that markup is zero.

Applebaum (1979) provides various specifications under which hypotheses of (non) competitive conduct can be tested. In each of these specifications, the supply relation (profit condition) containing the expression for markup is estimated along with equations representing the firm's variable cost function, as well as factor demand equations derived by applying Shepherd's Lemma to the variable cost function. Breshnahan (1988) points out that this modeling framework imposes restrictions implied by theory, lending precision and credibility to the estimates of the markup-related parameters.

This framework can be adapted to noncompetitive conduct in input markets as well (Schroeter 1988; Azzam and Pagoulatos 1990; Azzam and Schroeter 1991). The basic strategy is to determine whether firms' actions affect input prices and whether firms account for this effect when making input (and output) decisions. If so, their profit-maximizing output level is below that of the competitive firm and this has a depressing effect on fed cattle prices. Previous attempts seeking evidence of this market power effect in fed cattle markets have relied on aggregate time-series. Studies seeking evidence of market power using aggregate data assume *a priori* that all firms in the industry employ the same linear homogeneous production technology. If this assumption is inappropriate, the model is misspecified and results of statistical tests based on the model may be misleading. In this study, we use cost and revenue data from individual beef packing plants and avoid having to make restrictive assumptions about packer technology.

Static profit maximization is another maintained hypothesis of the Applebaum model. If producers are not unconstrained profit maximizers, the model is misspecified and test results are compromised. Some researchers have questioned the strict profit maximization hypothesis. For example, Azzam and Schroeter write, "If the dominant motivation of packing firms were some other goal, for example, profit-constrained market share maximization or any type of intertemporal objective, [our] results would be suspect." We examine whether the plant cost and revenue data are consistent with the assumption of static profit maximization using nonparametric analysis (Hanoch and Rothschild 1972; Varian 1984, 1985).

In the following section, we discuss, in detail, the theoretical model upon which our analysis is based. We then discuss the empirical model used to analyze packer conduct using plant cost and revenue data. In a subsequent section, we discuss the nonparametric analysis examining the maintained hypothesis of profit maximization. Finally, we discuss our findings and offer some concluding remarks.

2. A Theoretical Model for Analyzing Packer Conduct in Fed-Cattle Markets

Given that beef products are produced in fixed proportion to the cattle input, we assume that plants strive to maximize short-run profits. In the short run, we assume that firms' capital is fixed and cannot be altered. Once firms decide on the short-run profit-maximizing level of output, by definition they produce this output at minimum variable cost (given fixed capital). Formally, the problem for plant *i* in period *t* can be written as

$$\max \Pi_{it} = \quad P_{y,t} \;\; y_{it} \;\; \tilde{w}_{0,t} \;\; \gamma \;\; y_{it} \;\; \mathrm{VC}\,(\, \mathrm{w}_{1,t} \,, \ldots , \mathrm{w}_{n,t} \,; \mathrm{y}_{it} \,, \mathrm{z}_{i} \;)$$

where

Π_{ij} = profit of firm *i* in period *j*,
$P_{y,j}$ and y_{ij} = output price and quantity, respectively,
$\tilde{w}_0$ = the price or cost per unit of fed cattle,
γ = the inverse of the fixed proportion of slaughter converted to beef products,
VC = variable processing cost,
$w_{1,j}$ through $w_{n,j}$ = prices of non-cattle inputs, and
Z_i = the capital stock of firm *i*.

The first-order necessary condition for a maximum, assuming that each firm acts as a price-taker in the *output* market but influences prices in the fed cattle market, and generalizing across firms, is

$$\frac{\partial \Pi}{\partial y} \equiv P_y \;\; w_0 \;\; \frac{\partial w_0}{\partial y} \;\; y \;\; \frac{\partial \mathrm{VC}(\mathrm{w}_1;\; \mathrm{y},\; \mathrm{z}\;)}{\partial \mathrm{y}} \equiv 0$$

where $w_0 = \tilde{w}_0 \gamma$, and $\boldsymbol{w_1}$ is the vector of prices of non-cattle inputs.

The above specification suggests that plants choose output given knowledge of the change in price ensuing from an increase in plant output (cattle procurement), and take a fixed price in output markets. This behavioral condition is different from the condition for profit maximization by perfectly competitive producers in that it includes the term $-(\partial w_0/\partial y)y$ which would disappear if the packer's procurements did not influence fed cattle prices. Given an inelastic supply of fed cattle, increasing concentration among beef packers would lead to a measurable effect of individual procurement decisions on cattle price. Packers with market power produce at levels less than would be attained under competitive equilibrium, thus holding down the price of cattle.

In the conjectural variations model employed by Schroeter, the term $(\partial w_0/\partial y)y$ is decomposed into a supply elasticity and a ‘conjectural elasticity’ as follows:

$$\frac{\partial w_0}{\partial y} \; y = \frac{\partial w_0}{\partial Y}\frac{Y}{w_0}\frac{\partial Y}{\partial y}\frac{y}{Y} \; w_0$$
$$= \left(\frac{\partial Y}{\partial y}\frac{y}{Y} \right) w_0 \Big\rangle \left(\frac{\partial Y}{\partial w_0}\frac{w_0}{Y} \right) \Big\langle$$
$$= \left(\frac{A}{B} \right) w_0$$

It is clear that both components of this decomposition (A and B) cannot be identified in a regression model. In practice, estimates of the supply elasticity are obtained from other research. With a supply elasticity in hand, the conjectural elasticity can then be estimated. A test of market power, then, is a test of whether the conjectural elasticity is zero (A=0). If one is not interested in the conjectural elasticity, there is no need to decompose the term and one can test directly whether A/B is significantly different from zero. If the null hypothesis, $(A/B) = \alpha_0 = 0$, is not rejected, the implication is that packers do not influence prices in fed cattle markets.

The market power hypothesis is tested within a multi-equation model consisting of the cost function (or short-run variable cost function), input demand equations, and the first-order condition for profit maximization. Adding the input demand equations to the system serves to restrict the estimated parameters to be consistent with production theory, and lends precision to the estimate of the α_0 parameter (Breshnahan 1988). Formally, the model is

$$\mathrm{VC}_t = \mathrm{VC}\,(\, \mathrm{w}_{1t}, ..., \mathrm{w}_{nt}, \mathrm{y}_t, \mathrm{z}_t \;) + \mathrm{e}_{0t}$$
$$x_{lt} = \partial \mathrm{VC}\,(\, \mathrm{w}_{1t}, ..., \mathrm{w}_{nt}, \mathrm{y}_t, \mathrm{z}_t \;) / \partial \mathrm{w}_{lt} + \mathrm{e}_{it} \;\; \forall\, \mathrm{l} = 1, \mathrm{n}\text{-}1 \text{ or } \mathrm{n}$$
$$P_{yt} = (1 + \alpha_0)\, w_{0t} + \left.\frac{\partial \mathrm{VC}}{\partial \mathrm{y}}\right|_t + \mathrm{v}_t$$

where e_{0t}, e_{lt}, and v_t are prediction errors and x_{lt} are input demands.

Parameter restrictions are enforced to ensure that the (short-run) variable cost function is linearly homogeneous in prices, input demands are homogeneous of degree zero in prices, and symmetry holds. When the functional form of the variable cost function involves logged dependent and independent variables (as with the translog), x_{lt} are input cost shares. In this case, only n-1 input cost shares are included to avoid a singular covariance matrix of residuals. The system is estimated with the iterative seemingly unrelated regression estimator (ITSUR) or iterative three-stage least squares estimator (IT3SLS) if simultaneity problems are suspected.

3. Empirical Models

Azzam and Schroeter (1991) have argued that "... relevant cattle procurement markets are regional, not national, in scope." The implication is that if beef packers exercise market power, they influence prices in regional markets. We define two regional markets: the first extends from Nebraska to the Texas panhandle and includes southwestern Iowa and Colorado (a total of 21 plants processing steers and heifers); the second includes the Idaho panhandle and Washington (a total of 3 plants processing steers and heifers). The estimation and hypothesis tests are conducted for all plants with usable data in the two regions.

Primary data for the two regions were collected by GIPSA. Plants were divided into two groups based on the types of processing they undertook: plants that ship carcasses only versus plants that ship fabricated products. The planning period for beef packers was specified (in consultation with the Industry Analysis Staff at GIPSA) as a week.

Three variable factor inputs were specified: labor, fuels and electric, and other materials. Regular and overtime hours, and costs were reported weekly by respondents, and the price of labor each week was calculated as total labor cost divided by total (regular and overtime) number of hours.[1] Ideal indices (Fisher; Diewert 1976, 1978) were used to construct a weekly quantity aggregate for fuels and electricity after distributing monthly data reported by the plants to 6-day weeks over the reporting period. The price of fuels and electricity was calculated by dividing the total costs for fuels and electric by the quantity index. Quantities were not uniformly reported for water use, and quantities were not obtained for sewage treatment, packaging materials, and other materials. The cost of other materials is calculated as the sum of reported expenditures for water, sewage treatment, packaging materials, and other materials. A quantity index was built based on the level of output, and a price was calculated by dividing total costs due to other inputs by the output quantity index.[2]

Because of inconsistencies in reporting final product categories, output and cattle input were measured by the chilled carcass weight of cattle from slaughter. The price of input was calculated by dividing the total cost of purchasing cattle by the chilled carcass weight, while the

[1] Overtime hours never exceeded 23 percent of the total and were generally in the order of 5 to 10 percent of the total. Further, different plants might use different schedules for paying overtime: We treat the price of labor as a weighted average of regular and overtime hours.

[2] Other material costs are less than 10 percent of total costs generally, but it is acknowledged that the price of other materials is measured with error.

price of output was calculated by dividing total revenues less the cost of transfers of products and byproducts into the plant (net total revenues) by chilled carcass weight.

In the short-run variable cost model, one or more factors are treated as fixed. In our models, plant capacity is the fixed input. Designed maximum combined slaughter capacity in head per hour by plant is used as the measure of plant fixed input for plants that slaughter only. Designed maximum combined fabrication capacity in head per hour is used as the measure of plant fixed input for plants that ship fabricated beef products. Since some plants reported a change in the fabrication capacity from the beginning to the end of the study period, the average was used.[3]

3.1 Short-Run Variable Cost Model

In implementing the system described in equations (4)-(6) above, a short-run translog variable cost function was specified. This flexible functional form has the advantage of placing no restrictions on returns to scale, nor on substitutability of factors as price levels vary. The translog short-run variable cost system is

$$M_{l,t} = \delta_l + \sum_{m=1,2} \gamma_{lm} \ln\left(\frac{w_{m,t}}{w_{3,t}}\right) + \gamma_{l4} \ln y_t + \gamma_{l5} \ln z_t, \quad \text{for } l = 1,2$$

$$P_{y,t} - w_{0,t} = \left(1 + \alpha_0 + \sum_{k=1}^{n1} \alpha_k D_k\right) \frac{VC_t}{y_t}\left(\delta_4 + \gamma_{14} \ln(w_{1,t}/w_{3,t}) + \gamma_{24} \ln(w_{2,t}/w_{3,t}) + \gamma_{44} \ln y_t + \gamma_{45} \ln z_i\right)$$

$$\ln\left(\frac{VC_t}{w_{3,t}}\right) = \delta_0 + \sum_{l=1,2} \delta_l \ln\left(\frac{w_{l,t}}{w_{3,t}}\right) + \delta_4 \ln y_t + \frac{1}{2}\gamma_{44} (\ln y_t)^2 + \delta_5 \ln z_t$$
$$+ \frac{1}{2}\gamma_{11} \ln\left(\frac{w_{1,t}}{w_{3,t}}\right)^2 + \frac{1}{2}\gamma_{22} \ln\left(\frac{w_{2,t}}{w_{3,t}}\right)^2$$
$$+ \gamma_{12} \ln\left(\frac{w_{1,t}}{w_{3,t}}\right) \ln\left(\frac{w_{2,t}}{w_{3,t}}\right)$$
$$+ \sum_{l=1,2} \gamma_l 4 \ln\left(\frac{w_{l,t}}{w_{3,t}}\right) \ln y_t + \sum_{l=1,2} \gamma_l 5 \ln\left(\frac{w_{l,t}}{w_{3,t}}\right) \ln z_t$$
$$+ \gamma_{45} \ln y_t \ln z_t + \frac{1}{2}\gamma_{55} (\ln z_t)^2$$

where:
t subscripts observations,
VC_t = short-run variable processing cost,
y_t = the level of output,
$P_{y,t}$ = the price of output,
$w_{0,t}$ = the implicit price of cattle input,
$w_{1,t}$ = the aggregate price of fuels and electric,

[3] The change date was not available for any plant.

$w_{2,t}$ = the price of other inputs,
$w_{3,t}$ = the price of labor,
z_t = the capital input,
$M_{l,t}$ = the l^{th} factor's share in total variable costs,
n is the number of plants,
D_k = dummy variables indicating plants, and all others are unknown parameters.

Notice that, in this specification, the ratio of conjectural elasticity to supply elasticity $\left[(\partial Y)(y/Y)\right] / \left[(\partial Y)(w_0/Y)\right] = \alpha_i$ is estimated as a ratio that is permitted to vary across plants but is constant across time for individual plants. This assumption does not represent a big departure from past research. For instance, Azzam and Schroeter assume that the supply elasticity is constant. In addition, we assume that the conjectural elasticity is constant for individual firms.

Homogeneity and symmetry in prices are imposed on the system. In order to impose homogeneity in factor prices, the price of labor is used to scale variable costs and other factor prices. One input cost share is dropped from the system to avoid a singular error-covariance matrix. The entire system is estimated using ITSUR.

Theory requires that the estimated cost function be consistent with the properties of a short-run variable cost function: It must be (1) everywhere increasing in the price of the variable inputs, (2) non-decreasing in output, and (3) non-increasing in the fixed input. The cost function also must be symmetric and linearly homogeneous in the prices of the variable inputs (i.e., if all variable input prices increase by some proportion, *VC( )* must increase by the same proportion). Homogeneity and symmetry can be imposed to reduce the number of parameters to be estimated (Chambers 1988). The test for market power requires the estimated cost function to have properties consistent with the properties of the short-run variable cost function.

To see whether the short-run variable cost function has properties consistent with theory, a system imposing only cost-minimizing firm behavior is estimated first. This system consists of equations (7) and (8) above. For each of the two groups of plants, these systems were estimated using the (ITSUR) estimator. The results are reported in tables 1 and 2 for two categories of plants: one that includes plants that ship carcasses only, and another that includes all plants that ship any type of fabricated products. The estimation of the short-run variable cost function, along with factor share equations, yields parameters (see tables 1 and 2) which imply that short-run variable costs increase as the chain speed capacity increases, which is not consistent with the properties of short-run variable cost functions. This result may derive from the fact that chain speed is not a good measure of plant size, or that not all of the plants which have been pooled into the data set perform the same types of activities. In an attempt to overcome these possibilities, a fixed-effects model is estimated.

3.2 Fixed-Effects Model

The fixed-effects model permits differences in measures of capital across plants and in plant activities (e.g., different degrees of processing) to be modeled by including dummy variables for the plants in the cost function. For given levels of output and prices, variations in output and price have identical effects on costs across all plants, and the cost shares of the various inputs also are identical across plants.

Variable	Parameter Estimate	Standard Error	'T' ratio	'P' value
Intercept	35.202394	3.80224	9.26	0.0001
$\ln(w_1/w_3)$	-1.954276	0.04363	-44.79	0.0001
$\ln(w_2/w_3)$	-0.309753	0.07477	-4.14	0.0001
$\ln y$	-3.958657	0.61061	-6.48	0.0001
$\ln z$	3.444956	0.54138	6.36	0.0001
$\ln(w_1/w_3)^2$	0.125762	0.0012022	104.61	0.0001
$\ln(w_1/w_3)\ln(w_2/w_3)$	-0.023537	0.0014435	-16.31	0.0001
$\ln(w_2/w_3)^2$	0.119021	0.0047660	24.97	0.0001
$\ln(w_1/w_3)\ln y$	0.102224	0.0033650	30.38	0.0001
$\ln(w_2/w_3)\ln y$	0.0074647	0.0053881	1.39	0.1673
$(\ln y)^2$	0.305313	0.05078	6.01	0.0001
$\ln y \ln z$	-0.252151	0.04309	-5.85	0.0001
$\ln(w_1/w_3)\ln z$	-0.058646	0.0032554	-18.01	0.0001
$\ln(w_2/w_3)\ln z$	-0.053773	0.0055396	-9.71	0.0001
$(\ln z)^2$	0.324926	0.05856	5.55	0.0001

Variable	Parameter Estimate	Standard Error	'T' Ratio	'P' Value
Intercept	20.707934	2.59339	7.98	0.0001
$\ln(w_1/w_3)$	-2.796314	0.09937	-28.14	0.0001
$\ln(w_2/w_3)$	0.384261	0.02386	16.11	0.0001
$\ln y$	-1.895149	0.35970	-5.27	0.0001
$\ln z$	4.077639	0.40075	10.18	0.0001
$\ln(w_1/w_3)^2$	0.200010	0.0007475	267.56	0.0001
$\ln(w_1/w_3)\ln(w_2/w_3)$	-0.017600	0.0004442	-39.62	0.0001
$\ln(w_2/w_3)^2$	0.058865	0.0010209	57.66	0.0001
$\ln(w_1/w_3)\ln y$	0.126777	0.0085624	14.81	0.0001
$\ln(w_2/w_3)\ln y$	-0.037575	0.0019741	-19.03	0.0001
$(\ln y)^2$	0.156730	0.02639	5.94	0.0001
$\ln y \ln z$	-0.205143	0.03110	-6.60	0.0001
$\ln(w_1/w_3)\ln z$	-0.163245	0.01035	-15.77	0.0001
$\ln(w_2/w_3)\ln z$	0.00168799	0.0023487	0.72	0.4726
$(\ln z)^2$	0.278968	0.04571	6.10	0.0001

The empirical model can be written as

$$\ln\left(\frac{VC_t}{w_{3,t}}\right) = \alpha_0 + \sum_{k=1}^{n-1} \alpha_k D_k + \sum_{l=1,2} \delta_l \ln\left(\frac{w_{l,t}}{w_{3,t}}\right) + \delta_4 \ln y_t + \frac{1}{2}\gamma_{44}\left(\ln y_t\right)^2$$

$$+ \frac{1}{2}\gamma_{11} \ln\left(\frac{w_{1,t}}{w_{3,t}}\right)^2 + \frac{1}{2}\gamma_{22} \ln\left(\frac{w_{2,t}}{w_{3,t}}\right)^2$$

$$+ \gamma_{12} \ln\left(\frac{w_{1,t}}{w_{3,t}}\right) \ln\left(\frac{w_{2,t}}{w_{3,t}}\right) + \sum_{l=1,2} \gamma_{l4} \ln\left(\frac{w_{l,t}}{w_{3,t}}\right) \ln y_t$$

$$M_{l,t} = \delta_l + \sum_{m=1,2} \left(\gamma_{lm} \ln\left(\frac{w_{m,t}}{w_{3,t}}\right)\right) + \gamma_{l4} \ln y_t \quad \text{for } l = 1, 2$$

$$\frac{VC_t}{y_t} = \frac{1}{\delta_4 + \gamma_{14} \ln\left(w_{1,t} / w_{3,t}\right) + \gamma_{24} \ln\left(w_{2,t} / w_{3,t}\right) + \gamma_{44} \ln y_t}$$

where n is the number of plants in the data set.

Results for the fixed-effects models for the two groups of plants are presented in tables 3 and 4. The results suggest that the plants that only slaughter cattle operate in the region of increasing returns to scale (RTS = 1.52 at the mean of the data) as do those in the group that ship fabricated products (RTS = 1.11 at the mean of the data). (The means of the data necessary for computing returns to scale are in parentheses in tables 3 and 4.) The estimated fixed-effects cost models have properties consistent with theory; therefore these models may be used to test for market power. The validity of tests of market power still are contingent on the profit maximization assumption, an assumption we have not yet tested.

Variable	Parameter Estimate	Standard Error	'T' ratio	'P' value
Intercept	3.677106	2.41404	1.52	0.1294
ln (w_1 / w_3) (mean=7.87042)	-1.426161	0.03011	-47.36	0.0001
ln (w_2 / w_3) (mean=6.65656)	0.046801	0.04005	1.17	0.2440
ln y (mean=15.51985)	0.644758	0.30339	2.13	0.0349
ln $(w_1 / w_3)^2$	0.127505	0.0009915	128.59	0.0001
ln (w_1 / w_3) ln (w_2 / w_3)	-0.019629	0.0014530	-13.51	0.0001
ln $(w_2 / w_3)^2$	0.144358	0.0048726	29.63	0.0001
ln (w_1 / w_3) ln y	0.045716	0.0017403	26.27	0.0001
ln (w_2 / w_3) ln y	-0.046509	0.0024285	-19.15	0.0001
$(\ln y)^2$	-0.00234191	0.01931	-0.12	0.9036

[a] Estimates for intercept dummies are omitted to preserve confidentiality.

Variable	Parameter Estimate	Standard Error	'T' ratio	'P' value
Intercept	5.172352	1.93533	2.67	0.0078
ln (w_1 / w_3) (mean=10.30429)	-2.059459	0.06982	-29.50	0.0001
ln (w_2 / w_3) (mean=7.94698)	0.345950	0.02124	16.29	0.0001
ln y (mean=16.48129)	0.781232	0.19429	4.02	0.0001
ln $(w_1 / w_3)^2$	0.196237	0.0009768	200.90	0.0001
ln (w_1 / w_3) ln (w_2 / w_3)	-0.014698	0.0007316	-20.09	0.0001
ln $(w_2 / w_3)^2$	0.056598	0.0011539	49.05	0.0001
ln (w_1 / w_3) ln y	0.026501	0.0041872	6.33	0.0001
ln (w_2 / w_3) ln y	-0.035293	0.0013442	-26.26	0.0001
$(\ln y)^2$	0.00768246	0.01008	0.76	0.4463

[a] Estimates for intercept dummies are omitted to preserve confidentiality.

The test of market power is now conducted using the entire system outlined in equations (10) - (12). The system is estimated for both groups of packers. If the cost and revenue data collected are consistent with price-taking by fed-cattle buyers, the parameter α_0 will be not significantly greater than 0; if the data are consistent with price-influencing behavior, this same parameter will be in statistical terms significantly greater than zero.

Estimation results for both groups of packers are reported in tables 5 and 6. For all plants in both groups, the ratio of conjectural elasticity to price elasticity has the expected positive sign and is significant. Therefore, the null hypothesis of no market power is rejected. However, some parameter estimates, especially those associated with output terms, differ dramatically from estimates for the system without the profit-maximization equation included. For the group of plants that fabricate, the model that includes the profit-maximization condition suggests that the marginal cost curve has an inverted U-shape. The instability of the parameters with the addition of the equation for profit maximization and the unusually shaped marginal cost curve suggest that either one or both systems of equations are misspecified. In particular, the assumption of profit maximization may be inappropriate.

Variable	Parameter Estimate	Standard Error	'T' Ratio	'P' Value
Intercept	6.594699	2.40767	2.74	0.0068
$\ln(w_1/w_3)$	-1.424763	0.03037	-46.91	0.0001
$\ln(w_2/w_3)$	0.019669	0.04013	0.49	0.6246
$\ln y$	0.241717	0.30236	0.80	0.4250
$\ln(w_1/w_3)^2$	0.129126	0.0009753	132.39	0.0001
$\ln(w_1/w_3)\ln(w_2/w_3)$	-0.017869	0.0014299	-12.50	0.0001
$\ln(w_2/w_3)^2$	0.139913	0.0049246	28.41	0.0001
$\ln(w_1/w_3)\ln y$	0.044051	0.0017538	25.12	0.0001
$\ln(w_2/w_3)\ln y$	-0.043748	0.0024151	-18.11	0.0001
$(\ln y)^2$	0.025735	0.01923	1.34	0.1825
w_0	1.228569	0.01674	73.39	0.0001

[a] Estimates for intercept and slope dummies are omitted to preserve confidentiality.

Variable	Parameter Estimate	Standard Error	'T' Value	'P' Value
Intercept	-2.938303	1.83540	-1.60	0.1100
$\ln(w_1/w_3)$	-1.745513	0.06353	-27.48	0.0001
$\ln(w_2/w_3)$	0.323172	0.02136	15.13	0.0001
$\ln y$	1.492946	0.18948	7.88	0.0001
$\ln(w_1/w_3)^2$	0.197486	0.0009954	198.40	0.0001
$\ln(w_1/w_3)\ln(w_2/w_3)$	-0.014797	0.0007477	-19.79	0.0001
$\ln(w_2/w_3)^2$	0.054988	0.0011579	47.49	0.0001
$\ln(w_1/w_3)\ln y$	0.00671631	0.0037680	1.78	0.0752
$\ln(w_2/w_3)\ln y$	-0.033075	0.0013470	-24.55	0.0001
$(\ln y)^2$	-0.018857	0.01019	-1.85	0.0647
w_0	1.254770	0.02290	54.79	0.0001

[a] Estimates for intercept and slope dummies are omitted to preserve confidentiality.

4. Non-Parametric Analysis of Plant Cost and Revenue Data

The plant cost and revenue data are examined for consistency with the maintained hypothesis that they were generated by firms whose behavior is profit maximization (in a strict economic sense). Among other things, profit-maximizing firms equate marginal revenue to marginal costs. Profit-maximizing firms always choose the level of output that yields more profit than any other level of output. In the packers' case, short-run profit maximization implies that the only constraint on output decisions is plant capacity. For example, if plants seek a constant or minimum margin per head, they may make profits but do not maximize profits since they do not equate marginal revenues with marginal costs. Also, if plants produce some level of output predetermined by contract, they may not maximize profit since this level of output does not necessarily yield greater profits than all other levels of output. In this section, the hypothesis that packing plants maximize profits is tested using nonparametric methods.

The plant cost and revenue data provide weekly observations of prices and quantities over a 12-month period. We can, therefore, examine the data for individual plants for consistency with profit maximization. While data for some plants may be poorly measured, poorly measured data from a plant will affect the test of profit maximization for that plant only. Tests of profit maximization based on a regression analysis of data pooled from many plants could be compromised if a single plant submitted poorly measured data. Another advantage of performing the analysis for individual plants is to obviate the assumption that all of the plants in the pooled data perform similar types of activities. The nonparametric test only requires that each plant engage in similar activities each week.

By definition, given input and output prices, profits are maximized within a period if the input-output combination chosen in that period produces maximum possible profits. In particular for a given packing plant, it should be impossible to find a feasible input-output combination used in some other period that yields greater profits. It is this notion that forms the basis of the nonparametric test of profit-maximization. Data consistent with profit-maximizing behavior satisfy the Weak Axiom of Profit Maximization (WAPM) given by Varian. The original axiom is modified here slightly to account for the possibility that plants may influence prices in both inputs and output markets. Additionally, a violation is not counted unless an input-output combination can be found that increases profits by at least 5 percent (Hanoch and Rothschild, 1972).

Since the possibility that plants behave as oligopolists as well as oligopsonists is permitted, the first-order condition for a maximum differs slightly from that given in equation (2). The first-order necessary condition for a maximum, assuming that each plant influences prices both in the output market and the fed cattle market, and generalizing across firms, is

$$\frac{\partial \Pi}{\partial y} \equiv P_y + \frac{\partial P_y}{\partial y}\ y\ \ w_0\ \frac{\partial w_0}{\partial y}\ y\ \ \frac{\partial \mathrm{VC}(\, w_1;\ y,\ z\ )}{\partial \mathrm{y}} \equiv 0$$

where $w_0 = \tilde{w}_0\gamma$, and $\boldsymbol{w_1}$ is the vector of prices of non-cattle inputs.

The above specification suggests that plants choose output given knowledge of the change in input and output prices ensuing from an increase in plant output. This behavioral condition is different from the condition for profit maximization by perfectly competitive producers in that it includes the terms $[(\partial w_0/\partial y)y]$ and $[(\partial P_y/\partial y)\ y]$ which would disappear if the packer's actions did not influence fed-cattle prices or the prices of processed beef.

The nonparametric tests reflect the potential for oligopolistic behavior as well as oligopsonistic behavior. The following comparison is made using input-output combinations from the current week and other weeks, where current week input and output prices are adjusted according to the subsequent rules:

where:
Q_j = a netput vector in period j
y_j = output in period j
$\boldsymbol{X_{1,j}}$ = a vector of non-cattle inputs in period j
y_k = output in period k
$P_{y,k}$ = the price of output in period k
$w_{0,k}$ = the implicit price of cattle input in period k
$\boldsymbol{w_{1,k}}$ = a vector of prices for inputs in $\boldsymbol{X_{1,k}}$
η = the ratio of conjectural elasticity to supply elasticity
ε = the ratio of conjectural elasticity to demand elasticity

As before, the terms $[(\partial w_0/\partial y)y]$ and $[(\partial P_y/\partial y)\ y]$ may be expressed as the ratio of conjectural elasticity to supply elasticity (times w_0) and the ratio of conjectural elasticity to demand elasticity (times P_y), respectively. We now compose a grid of these elasticity ratios and perform the nonparametric tests of profit-maximization using many different pairs of elasticity ratios. The purpose is to see if we can find a pair of elasticity ratios for which the data are consistent with profit-maximizing behavior of the plants. In this experiment, the ratio of conjectural elasticity to supply elasticity is permitted to range from 0 to 2.0 and the ratio of conjectural elasticity to demand elasticity ranges from -3.0 to 0. Profit-maximizing behavior of competitive firms is tested when both ratios are set to zero.

Each pairwise comparison that violates the axiom is counted. The total number of violations divided by the total number of comparisons performed (the square of the number of weeks) is calculated as the proportion of bundles in violation. In addition, we also count the number of weeks in which an alternate bundle was found to yield a higher "profit" than the actual bundle chosen, i.e., at least one violation of the axiom occurred. The number of weeks for which a violation occurred divided by the total number of weeks observed is reported as the proportion of periods which failed the WAPM. In combination, the two measures can be interpreted as follows:

1) If the percentage of observed *periods* in violation of WAPM is zero, and the percentage of *bundles* in violation also is zero, then the data are said to rationalize static profit maximization.
2) If the percentage of bundles in violation is not zero, but the proportion of periods in violation is low, then the data are said to *possibly* rationalize static profit maximization.
3) If the percentage of weeks in violation is high (greater than 20-25 percent over the 48-49 weeks (11 months) for which we have usable observations), then the data are said not to rationalize static profit maximization.

The test of profit maximization is conducted four times using data aggregated to different levels. The first and second tests are based on plant data aggregated to the weekly and monthly levels, respectively. The third and fourth tests use firm-level data aggregated to the weekly and monthly levels, respectively. In each of these tests and for each plant (firm), we search for the pairs of ratios that minimize pairwise violations of WAPM and, separately, the percentage of periods when at least one pairwise violation of WAPM occurs. As previously stated, a violation is not counted unless an input-output combination can be found that increases profits by at least 5 percent.

Results of the four tests are presented in tables 7 - 10. To ensure confidentiality, only results for a small set of randomly selected plants and firms are reported. The selected plants and firms may vary from table to table. For the randomly selected plants and firms, we report five pairs of ratios (conjectural elasticity to supply elasticity and conjectural elasticity to demand elasticity). Each reported pair of ratios either (nearly) minimizes the percentage of violations of WAPM and/or (nearly) minimizes the percentage of periods where at least one violation of

WAPM occurs.[4] In the last two columns, we report the percentage of pairwise violations of WAPM and the percentage of periods where at least one violation of WAPM occurs associated with these particular ratios. In addition, we report the average and average absolute differences between current output level and profit-maximizing output level. Lastly, we report the number of periods for which selected output was greater (less) than profit-maximizng levels of output.

It is easy to summarize the results in these tables. Further analysis of the data pointed to three facts inconsistent with profit-maximizing behavior. First, the average absolute deviation from profit-maximizing output levels in percentage terms is quite large; that is, if plant managers are attempting to maximize profits then they are making large mistakes on average (as high as 16 percent for some plants). Second, the errors in output decisions do not appear to be random. About 80 percent of output levels are below levels that maximize profits. If the errors were random, only 50 percent of output levels should be below profit-maximizing levels.

Lastly, plant managers make profit-maximizing mistakes (of at least 5 percent) about 60 - 70 percent of the time whether the period is defined as a week or a month (see tables 7 and 8). From tables 9 and 10, it is evident that the data are no more consistent with profit maximization at the firm level than at the plant level. The number of periods during which firm level profits could have been higher is still 60 percent or greater. Taken together, these three results provide powerful evidence that beef packing plant managers do not strive to maximize profits in a strict, classical sense.

[4] It is not possible to identify a unique pair of ratios that minimizes the number of violations of WAPM and/or the number of periods when there is at least one violation of WAPM.

5. Summary and Conclusions

Using plant-level data collected by GIPSA, researchers in the Department of Agricultural and Applied Economics at Virginia Tech tested the hypothesis that beef packers exercise market power and influence cattle prices. Plants with market influence produce a level of output below that of a perfect competitor, and in the process, depress cattle prices. The test was conducted using a conjectural variations model that assumes plants recognize their market influence and adjust their output levels in a manner consistent with profit maximization. Packers were divided into two groups: those who slaughter only, and those who slaughter and fabricate.

GIPSA undertook an heroic effort to collect the data necessary to conduct the hypothesis test. For 42 plants (including 24 plants in the defined market areas used in this study), GIPSA personnel used a mail survey and any needed telephone follow-up to collect 63 data items on a weekly basis and 33 additional data items on a monthly basis for a period of 1 year. Every effort was made to correct errors of omission and data entries that seemed inconsistent with responses elsewhere. In spite of these efforts, some data problems remained. Aside from errors of omission and misreported data, there is some evidence that concepts such as plant capacity were not measured consistently across plants.

Tests of market power conducted within the conjectural variations model hinge critically on two factors. First, the cost function that underpins the model must be well-specified and exhibit properties consistent with economic theory. Second, the model assumes a very strict notion of profit-maximizing behavior on the part of packing plants.

Table 7. Minimum violations of WAPM in weekly plant data

Plant	Ratio Conjectual Elasticity to Supply Elasticity	Ratio Conjectual Elasticity to Demand Elasticity	Average difference between chosen and Π maximum[a] level of output as percentage of chosen output	Average absolute difference between chosen and Π maximum level of output as percentage of chosen output	Number of weeks Π maximum Output was less than chosen output	Number of weeks Π maximum Output was greater than chosen output	Percentage of pairwise comparisons of weekly activity programs violating WAPM by more than 5 percent	Percentage of periods when at least one pairwise comparison violates WAPM by more than 5 percent
01								
	0	-0.12	4.94%	11.73%	30	17	2.71%	22.45%
	0.01	-0.11	5.12%	11.90%	30	17	2.83%	24.49%
	0.07	-0.06	4.89%	12.13%	30	17	2.92%	24.49%
	0.13	-0.01	4.89%	12.13%	30	17	3.08%	30.61%
	0.14	0	4.89%	12.13%	30	17	3.12%	30.61%
02								
	0	-0.05	-8.60%	12.36%	11	34	14.83%	67.35%
	0.01	-0.04	-8.24%	12.73%	11	34	14.70%	65.31%
	0.03	-0.02	-8.24%	12.73%	11	34	14.45%	63.27%
	0.04	-0.01	-7.79%	12.31%	12	33	14.49%	63.27%
	0.05	0	-7.11%	12.53%	13	32	14.49%	65.31%
03								
	0	-0.19	-5.89%	15.45%	15	32	18.20%	83.67%
	0	-0.18	-5.53%	15.61%	16	31	17.49%	85.71%
	0	-0.14	-2.18%	15.36%	21	26	17.37%	91.84%
	0.14	-0.06	-5.53%	15.61%	16	31	18.28%	87.76%
	0.15	-0.05	-5.13%	16.00%	16	31	18.24%	87.76%
04								
	0	-0.12	-13.73%	16.34%	7	42	26.36%	74.00%
	0	-0.1	-10.82%	16.22%	13	37	25.52%	78.00%
	0	-0.09	-9.60%	16.28%	14	35	24.88%	80.00%
	0.1	0	-9.17%	16.61%	15	34	26.00%	82.00%
	0.12	0	-10.91%	16.77%	12	38	26.84%	80.00%
05								
	0	-0.17	-14.57%	15.14%	2	46	34.32%	81.63%
	0	-0.11	-9.14%	12.12%	11	37	27.45%	85.71%
	0.14	-0.05	-14.15%	14.82%	3	45	34.65%	81.63%
	0.15	-0.04	-14.15%	14.82%	3	45	34.57%	81.63%
	0.12	0	-8.28%	12.05%	13	35	27.28%	89.80%

[a] "Π maximum" denotes "profit-maximizing."

Table 8. Minimum pairwise violations of WAPM in monthly plant data

Plant	Ratio Conjectual Elasticity to Supply Elasticity	Ratio Conjectual Elasticity to Demand Elasticity	Average difference between chosen and Π maximum[a] level of output as percentage of chosen output	Average absolute difference between chosen and Π maximum level of output as percentage of chosen output	Number of periods Π maximum Output was less than chosen output	Number of periods Π maximum Output was greater than chosen output	Percentage of pairwise comparisons of monthly activity programs violating WAPM by more than 5 percent	Percentage of periods when at least one pairwise comparison violates WAPM by more than 5 percent
01								
	0	-0.16	-12.10%	12.10%	0	10	0.00%	0.00%
	0	-0.11	-12.10%	12.10%	0	10	0.00%	0.00%
	0	-0.1	-12.10%	12.10%	0	10	0.00%	0.00%
	0.02	-0.08	-12.10%	12.10%	0	10	0.00%	0.00%
	0.08	-0.03	-12.10%	12.10%	0	10	0.00%	0.00%
02								
	0	-0.03	-1.06%	13.00%	5	4	21.49%	36.36%
	0.01	-0.02	-1.06%	13.00%	5	4	22.31%	36.36%
	0.02	-0.01	-1.06%	13.00%	5	4	23.14%	36.36%
	0.03	0	-1.06%	13.00%	5	4	23.14%	36.36%
	0.04	0	-12.50%	13.18%	1	7	22.31%	45.45%
03								
	0	-0.06	-4.72%	9.20%	4	7	18.18%	81.82%
	0	-0.04	4.61%	6.58%	7	3	30.58%	63.64%
	0.01	-0.05	-4.72%	9.20%	4	7	18.18%	81.82%
	0.02	-0.04	-4.72%	9.20%	4	7	19.01%	81.82%
	0.07	0	-4.72%	9.20%	4	7	19.83%	90.91%
04								
	0	-0.11	0.82%	9.29%	5	5	7.44%	36.36%
	0.01	-0.1	1.08%	9.55%	5	5	7.44%	36.36%
	0.02	-0.09	-0.26%	10.36%	5	6	7.44%	36.36%
	0.04	-0.08	-0.26%	10.36%	5	6	8.26%	36.36%
	0.05	-0.07	0.00%	10.63%	5	6	8.26%	36.36%
05								
	0	-0.07	-6.00%	11.33%	1	8	27.27%	63.64%
	0.01	-0.06	-6.00%	11.33%	1	8	27.27%	63.64%
	0.02	-0.05	-5.39%	11.94%	2	8	27.27%	63.64%
	0.07	-0.01	-6.00%	11.33%	1	8	28.10%	63.64%
	0.08	0	-6.00%	11.33%	1	8	27.27%	63.64%

[a] "Π maximum" denotes "profit-maximizing."

Table 9. Minimum pairwise violations of WAPM in weekly cost and revenue data aggregated for Firms

Firm	Ratio Conjectual Elasticity to Supply Elasticity	Ratio Conjectual Elasticity to Demand Elasticity	Average difference between chosen and Π maximum[a] level of output as percentage of chosen output	Average absolute difference between chosen and Π maximum level of output as percentage of chosen output	Number of weeks Π maximum Output was less than chosen output	Number of weeks Π maximum Output was greater than chosen output	Percentage of pairwise comparisons of weekly activity programs violating WAPM by more than 5 percent	Percentage of periods when at least one pairwise comparison violates WAPM by more than 5 percent
01								
	0	-0.05	-5.40%	13.68%	20	28	43.10%	91.67%
	0.01	-0.05	-8.12%	14.71%	17	31	44.18%	89.58%
	0	-0.04	0.26%	11.97%	24	24	43.19%	89.58%
	0.02	-0.04	-8.83%	15.32%	16	32	44.14%	89.58%
	0.07	0	-9.82%	16.17%	14	34	44.53%	89.58%

[a] "Π maximum" denotes "profit-maximizing."

Table 10. Minimum pairwise violations of WAPM in cost and revenue data aggregated for firms to monthly periods

Firm	Ratio Conjectual Elasticity to Supply Elasticity	Ratio Conjectual Elasticity to Demand Elasticity	Average difference between chosen and Π maximum[a] level of output as percentage of chosen output	Average absolute difference between chosen and Π maximum level of output as percentage of chosen output	Number of months Π maximum output was less than chosen output	Number of months Π maximum output was greater than chosen output	Percentage of pairwise comparisons of monthly activity programs violating WAPM by more than 5 percent	Percentage of periods when at least one pairwise comparison violates WAPM by more than 5 Percent
01								
	0	-0.04	-0.47%	6.06%	5	6	23.97%	63.64%
	0.01	-0.04	-2.10%	6.45%	4	6	17.36%	63.64%
	0.02	-0.03	-1.49%	7.07%	5	6	17.36%	63.64%
	0.04	0	-0.47%	6.06%	5	6	27.27%	63.64%
	0.05	0	-1.49%	7.07%	5	6	19.01%	72.73%

[a] "Π maximum" denotes "profit-maximizing."

Misspecification with regard to either of these factors renders hypothesis tests invalid. Our strategy was to first identify a suitable cost function specification. Cost functions were estimated as part of a cost system that included the cost function and input demand equations. Once a cost function was found that exhibited properties consistent with theory, the hypothesis test was performed using a system of equations that included cost function, input demand equations, and an equation enforcing the profit-maximization condition that marginal revenues equal marginal costs.

The possibility that data measurement problems affected regression results first surfaced when estimating a short-run cost system where plant capacity was treated as fixed. The estimated cost function had properties inconsistent with theory. Replacing the short-run cost system with a fixed-effects system appeared to solve the problem in the sense that the fixed-effects cost model had properties consistent with theory. One possible explanation of this finding is that chain speed, the measure used, does not accurately capture the influence of differences in physical plant on processing costs.

The hypothesis that plants do not exercise market power was tested using the fixed-effects system model that included the profit-maximization condition. For both groups of plants, the hypothesis is rejected. However, for both groups, the parameter estimates for the system with the profit-maximization condition differed so much from the original cost system that the assumption of profit-maximization appeared inappropriate.

Using nonparametric tests of a modified Weak Axiom of Revealed Preference, the underlying assumption of profit maximization was tested for individual plants and firms while permitting them to behave as perfect competitors, oligopsonists, and/or oligopolists. Thus, poor data from one plant could not affect the results for another plant. The assumption of profit maximization was rejected for almost all plants and firms.

For only one reported plant can a pair of elasticities be found for which the profit-maximization hypothesis is not rejected. In general, the number of pairwise violations and number of weeks in which profit-maximizing errors are made are at a minimum for elasticity ratios close to zero. That is, the data are most consistent with the profit-maximization hypothesis when the degree of market power is minimal in both the input and output markets. However, even for these pairs of elasticity ratios, the evidence against the profit-maximization model, as currently constructed, is very strong.

Further analysis of the data pointed to three facts inconsistent with profit-maximizing behavior. First, the average absolute deviation from profit-maximizing output levels in percentage terms is quite large; that is, if plant managers are attempting to maximize profits then they are making large mistakes on average (as high as 16 percent for some plants). Second, the errors in output decisions do not appear to be random. About 80 percent of output levels are below levels that maximize profits. If the errors were random, only 50 percent of output levels should be below profit-maximizing levels (this is also true for the oligopolist/oligopsonist even though profit-maximizing levels are below that of the perfect competitor). Last, plant managers make profit-maximizing mistakes in almost every period whether the period is defined to be a week or a month. Taken together, these three results provide powerful evidence that beef packing plant managers do not strive to maximize profits in a strict, classical sense.

Although past research has relied heavily on the conjectural variations model to search for evidence of market power in the beef packing industry, we believe this model is inappropriate. Although there is a small possibility that improvements in data collection would resolve the many violations of profit maximization, this possibility is remote. We doubt that any new data collection effort would make improvements to the data significant enough to alter the overwhelming evidence against the profit-maximization hypothesis.

Where do we go from here? The behavior of packers needs to be better documented. Do they strive to maintain some margin? Do they fabricate mostly on long-term contract? Once their behavior is better understood, perhaps a more appropriate model can be constructed to test the market power assumption. It certainly is possible, though, that their actual behavior may be such that it does not lend itself to feasible tests of the market power hypothesis. In part, this is why the profit-maximization assumption is so appealing and so widely used; it lends itself to feasible tests of market power. But the results of this analysis, using plant-level data heretofore not available, suggest the test is not appropriate as a test for market power or as an aid to Federal agencies charged with monitoring and/or regulating the beef packing industry.

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