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March 26, 1999

Dr. Gerald Grinnell
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Dear Gerry:

I enclose my review report on the GIPSA Texas Panhandle study. As I noted in a prior email to you, I am enclosing as an addendum to the report, a short conceptual paper by Mingxia Zhang and myself that looks at the issue using a spatial markets modelling paradigm. This paper is in a rather rough draft form and should not be quoted or circulated beyond those involved directly in the GIPSA study.

Thank you for the opportunity to participate in this review. It was an interesting experience, and I hope I have the opportunity to work with you again.

Sincerely,

Richard J. Sexton
Professor

RECEIVED 4/6/99

Fed Cattle Procurement Investigation in the Texas Panhandle

Review conducted by Richard J. Sexton
University of California, Davis

In this review of the GIPSA investigation of cattle procurement in the Texas Panhandle, I will attempt to answer four questions posed by GIPSA in requesting my review:

- Did GIPSA ask the right questions?
- Did GIPSA collect the right data?
- Did GIPSA conduct the right analyses?
- Did GIPSA reach the correct conclusions?

The bulk of my review focuses on the economic and statistical analysis conducted by Professors Schroeter and Azzam on behalf of GIPSA.

Did GIPSA Ask the Right Questions?

The record reveals that GIPSA has been concerned about rising concentration in the beef packing industry and increasing use by the industry of complex and sophisticated pricing methods. GIPSA is concerned whether packers' use of no-cash procurement methods has the effect of depressing cash prices. More generally GIPSA has expressed concern whether procurement of cattle is associated with "unfair, unjustly discriminatory, or deceptive practices to the detriment of livestock feeders and producers." I agree that these are important and reasonable questions to pose in a region where some 300 feedlots sell cattle to two, three, or at most four packers. In addition to concern about packers' specific pricing practices, I believe it would have been useful to pose the more general question of the extent, if any, to which packers in this region exercise oligopsony power to feeders' detriment.[1]

Did GIPSA Collect the Right Data?

The investigation has involved a detailed and sophisticated data gathering process that included documenting every cattle procurement transaction by the three packers located in the Panhandle region for the 16 month period from February 1995 - May 1996. GIPSA did an excellent job of data collection and data summarization. GIPSA also collected detailed information on the various marketing agreement contracts offered in the region. In addition, GIPSA staff conducted thoughtful interviews with a number of feedlot managers. These interviews are a very useful complement to the formal data collection. The only piece of information not collected (to my knowledge) that would have been helpful is information on packers' processing costs. Packing cost information coupled with the detailed price information that was collected would have

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[1]A memorandum from James Baker to Assistant Secretary Dunn indicates that "a major emphasis for the Texas investigation will include an evaluation of competition between the three major slaughter firms." A draft work plan also refers to the goal of creating "monthly supply and demand curves from 1970 to May 1996." However, the file does not include evidence that evaluation of this type was conducted.

cost information coupled with the detailed price information that was collected would have enabled an econometric analysis of packer margins to be undertaken to answer questions regarding the possible exercise of oligopsony power in the region.

Did GIPSA Conduct the Right Analyses?

The investigation file compiled by GIPSA is an admirable summary and graphical interpretation of the extensive data gathering conducted by GIPSA. The principal statistical and economic analysis was undertaken on contract by Professors Schroeter and Azzam. This review focuses on their analysis.

The Schroeter and Azzam Analysis

Professors Schroeter and Azzam (SA) are both highly respected economists with extensive experience in analyzing concentrated industries and the beef industry in particular. Their selection to conduct this part of the analysis represents an excellent choice by GIPSA. I first examine the econometric analysis of the relationship between captive supplies and spot market prices, then I evaluate the economic arguments offered by SA to explain the negative correlation indicated in the data.

I. The Econometric Analysis

As SA note, various prior studies have revealed a negative statistical correlation between packers' use of captive supplies in a region and that region's spot market price. SA find the same, statistically significant relationship in the Panhandle region. In general, their econometric analysis is quite convincing in demonstrating the existence of an inverse relationship between spot price and captive supplies at both the packer and the regional market level. My principal concern with the analysis pertains to the possible sensitivity of results to model selection. Because there is no structural model to underpin either the firm-level or regional analysis, any empirical model is necessarily somewhat ad hoc and best interpreted as a loose reduced form specification.

I would like to be assured that the results for the captive supply variables for both hypothesis 1 (H1) and hypothesis 2 (H2) are robust to alternative plausible specifications of the regression equations. In particular, the quadratic time trends in equation (1) are somewhat bothersome. No explanation is given for their inclusion, so the reader is left to infer that they are there primarily because they "fit" the data. The need to rely on trend terms in a time series of such short duration may be evidence of important explanatory variables that are excluded from the model. Exclusion of relevant variables need not bias the captive supply coefficients, but it would be useful to know whether the price - captive supply relationship is robust to plausible alternative model specifications. Nonetheless, given that the same relationship has been observed in other studies, it is reasonable to conclude that the Panhandle data support rather strongly H1 and H2.

II. The Economic Interpretation

SA note correctly that correlation between captive supplies and the cash price need not imply that large captive supplies cause low spot prices. They offer conceptual explanations for the results in support of H1 and H2 in section VII of their report. In terms of H1, they argue that packers who have secured a large percentage of their current slaughter requirements from captive supplies will be able to bid conservatively in the spot market and, accordingly, procure their remaining supply from the low end of the price distribution. They offer an alternative explanation for evidence in support of H2 (the negative relationship between regional prices and captive supplies) based on packers' and feeders' incentives in scheduling deliveries of captive supply cattle. Although the SA explanations are plausible, I do have some problems with their analysis, and I think other, less innocent explanations are also plausible. One concern is the bidding process for spot market cattle in the Panhandle region and the attendant implications for overall spot prices of the "conservative" bidding discussed by SA.

The bidding process for Panhandle cattle

Regional prices are the cumulative outcome of individual packers' bidding behavior. Thus, I am concerned when the explanation by SA in support of H1 is abandoned when seeking an explanation for H2. SA argue that "conservative" bidding by packers who have procured a large share of their immediate slaughter needs from captive supplies need not influence the overall market price. I doubt it. Even a cursory analysis of the spot market bidding process reveals that it is heavily skewed in favor of the packers, and any forces that diminish a packer's incentives to bid aggressively for cattle are likely to adversely affect cash prices.

This conclusion is based first on the obvious concentration disparity between buyers and sellers. Whereas it is true in a competitive market that removing a given fraction of output from both the demand and the supply side of the market has no effect on the market price, this result need not be true under imperfect competition. At most three to four buyers are available to bid on a feeder's show list, while the record indicates that 339 feeders sold cattle to the three major packers included in the Panhandle study. It is plausible, even likely, that the conservative bidding described by SA will affect the overall price distribution in a market of this structure.[2]

The second basis for concern about the competitiveness of the bidding process and the effect of captive supplies on the process is that the bidding mechanism itself is poorly designed to serve feeders' interests. A bidding process where the same three or four buyers interact repeatedly through time and among many sellers is a process that is tailor made for bidder collusion. The current structure of the bidding process probably reflects packers' power to

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[2]A very simple illustration can help to make this point. Suppose we have a region with 300 identical feeders and 3 identical packers. Suppose the initial setting features a pure spot market. Then suppose one packer procures his entire supply through contracts with 100 feedlots. I think that most everyone familiar with bidding, bargaining, and auctions would agree that a structure with 2 buyers and 200 sellers is less favorable to the sellers than a structure with 3 buyers and 300 sellers.

implement a bidding process that is favorable to them.

Bidding is undertaken in an auction format, but the structure and implications of the bidding process for pricing have not been analyzed as part of the GIPSA study, an important omission in my opinion. A first problem is that packers by convention only bid whole dollar amounts per hundred weight. We can assume reasonably that packers have good knowledge of their own costs and market valuation of finished beef. Thus, they know with considerable accuracy the value per hundred weight of a pen of cattle at any point in time--the cattle's marginal revenue product. A packer should be willing to bid up to this marginal revenue product to procure cattle, but he will never bid more. Thus, suppose a buyer values a pen of cattle at $73.75 per cwt. Under the current bidding convention, he will never bid more than $73.00. Panhandle packers all face similar market conditions for sale of their finished products, so differences among them in valuing cattle will be due primarily to differences in processing costs. Although we lack information on packing costs, it is reasonable to assume that any differences among packers will be small. Given similar valuations among processors and the whole-dollar bidding convention, the outcome, as affirmed repeatedly in the interviews with feedlot managers, is that feeders bid the same (whole dollar) price.

To get a rough estimate of the cost to panhandle feeders of the whole dollar bidding convention, suppose reasonably that the average marginal valuation in excess of the nearest whole dollar is $0.50. Multiply this amount by the number of spot market cattle and the average hundred weight of those cattle to get an estimate of the total loss:

6,217,635	head sold from 2/6/95 - 5/16/96
x 0.7089	fraction sold in the cash market
x 11.42	average hundred weight per head.
x 0.50	average marginal valuation in excess of whole dollar
= $25,167,861	estimated dollar loss to feeders during study period

Because most buyers bid the same amount, a nonprice, queuing mechanism is used to distribute cattle to buyers, wherein the first bidder has priority in the case of tie bids. A second design problem with the bidding process is that the first bidder in line is given an opportunity to revise his bid in the event that someone bids higher. Thus, the key feature in securing the cattle, is not to make a high bid but, rather, to secure the first bid. It need not be the buyer's "best" bid because he knows he will be able to revise it in the event that a higher bid is received. It is probably easy for buyers to agree to queuing conventions among themselves. Given the way bidding is structured, queuing and not pricing determines who gets the cattle.

A third problem with the bidding process is mandatory price reporting. Whole dollar bidding conventions, and nonprice queuing rules are possible outcomes of a collusive bidding process. A key defense against collusive bidding is that any individual bidder has incentives to cheat on the arrangement. In the present case, cheating would be reflected by secret bids above an agreed upon price. These bids must be secret, or they will expose the bidder to retribution by the other buyers. Thus, mandatory price reporting, such as is mandated in proposals currently before Congress, serve only to reinforce collusive bidding arrangements. Indeed, the GIPSA analysis revealed many transactions at prices above the reported maximum.[3] The interviews with feedlot managers revealed that nonreporting was often a conscious attempt by the seller to protect a buyer against revelation that the buyer had paid an especially high price for the cattle. Mandatory price reporting is most likely harmful to sellers for this reason.

In sum, SA are correct in arguing that a buyer will bid "conservatively" when he has a large inventory of captive supply cattle for the current market window. I think they err in failing to analyze the structure of the spot market bidding mechanism and to recognize that conservative bidding by one or more of the three to four active bidders in the region may adversely affect regional spot prices.

SA's explanation in support of H2

SA argue that the inverse relationship between spot prices in the panhandle region and the volume of deliveries from captive supplies may be due to scheduling decisions by market participants' in response to market signals. Because cattle are normally delivered with about a week's lag, they argue that high cash prices in week t will cause increased deliveries of captive supply cattle for slaughter in week t+1. Both packers and feeders share the same incentive in this regard. Packers can substitute captive supply cattle for expensive cash market cattle, and, because many formula contracts base payments for week t deliveries on the t-1 cash price, feeders with formula contracts can lock in a favorable price. For similar reasons, SA argue that an expectation at time t of a high cash price in period t+1, i.e., $E_t[P_{t+1}]$, will reduce captive supply deliveries for slaughter in period t+1, instead deferring delivery to period t+2. This argument is formalized by SA as Hypothesis 3 (H3).

In essence, SA argue plausibly that both feeders and packers with captive supply contracts can use those contracts to engage in intertemporal arbitrage in relation to the cash market. I believe an important conceptual flaw in their argument is their failure to consider that participants in the cash market have the same incentives, and, because the cash market is quantitatively larger than the spot market, the impacts of this arbitrage activity will have an important influence on the constellation of week-to-week cash prices. For example, a feeder who expects next week's cash price to be higher than the current price ($E_t[P_{t+1}] > P_t$) has incentive to withhold cattle from the market for sale the following week. Similarly, packers with the same price expectations will, to the extent they can hold cattle in inventory, bid aggressively to purchase cattle in period t.[4] The result of this arbitrage activity is to raise price in period t relative to period t+1 so that $P_t = E_t[P_{t+1}]$, except possibly for any transactions costs

[3] Steer prices were found above the reported maximum for 91 days during the study period.

[4] The "days out" analysis conducted by GIPSA reveals packer flexibility in this dimension. Two thirds of cattle were slaughtered within 7 days of purchase, but one-third we held 8 or more days before slaughter. Statistics on packer inventory of cattle also reveal considerable variability over time, behavior consistent with intertemporal arbitrage in the spot market by packers.

associated with this type of arbitrage.[5] The relationship $P_t = E_t[P_{t+1}]$ says that the cash cattle price is a martingale. Noted authors such as Alchian (1974) argue that essentially all prices are martingales, so we should not be surprised if such a relationship holds for beef.

However, if the cash price in the Panhandle region is a martingale, it means that there are no opportunities to use captive supply cattle to arbitrage the cash market in the manner proposed by SA. SA do provide some empirical evidence in support of H3 based on estimation of their equation (2). However, it is not very convincing. As the authors acknowledge, there is an omitted variable problem. We are also given little information about the performance of the error term in these regressions. Also, based on the arguments I have raised here, P_t and $E_t[P_{t+1}]$ should be highly correlated, making it difficult to separate their individual influences on captive supply deliveries. Finally, given the precarious state of the conceptual argument in support of H3, one-tailed tests are probably not appropriate. Under a two-tailed test, only 5/16 coefficients on P_t are significant and 7/16 of the coefficients on P_{t+1} are significant.[6]

A Spatial Model of the Captive Supply - Cash Price Relationship

Most analyses of the link between captive supplies and the cash market have not studied the relationship within a unified model framework with optimizing agents. The SA analysis discussed in the previous section is incomplete in that it does not arise from an explicit optimization framework. For example, SA argue that packers with a high volume of captive supplies can bid conservatively on the cash market. Based on this argument, packers can lower their cash procurement costs through use of captive supplies. This would mean that, if captive supply contracts can be secured at prices no greater than anticipated cash prices, captive supplies can be used to depress payments to feeders. Although this conclusion seems to flow logically from SA's own analysis, it is contrary to the conclusions they draw.

This inferential problem arises from failure to consider captive supplies from a framework of both packer and feeder optimization. In an attachment to this report, Mingxia Zhang and I offer such a model using a spatial markets modelling paradigm. We use a stylized duopsony model to show how packing plants can use a region of captive supply contracts to effectively create a buffer area that diminishes or eliminates competition in the cash market. Packers increase their profits at feeders' expense in this model by offering captive supply contracts in the region near their market boundaries. We show that feeders will rationally sign these contracts even though they know that the effect of the contracts is to depress the spot

[5]In the present context such costs for feeders might be costs associated with holding cattle a week longer than the desired feeding period.

[6]The acknowledged omission of relevant variables probably means that the estimated variances are biased upwards, which may cause the hypothesis to be rejected too often.

market price.[7]

The Zhang-Sexton (ZS) model, thus, shows how packers can use captive supply contracts to depress the spot market price, the empirical result attained by SA and others. We do not suggest that our model represents a definitive explanation for the empirical regularity, especially in light of the problem discussed in footnote 7.[8] Rather, I offer the ZS model for three reasons: First, it illustrates the type of equilibrium analysis that is helpful to understand packers' incentives to use captive supply contracts and the effect of these contracts on cash prices. Second, the ZS model shows how captive supply contracts can be used to manipulate the market to feeders' detriment. Models of this genre deserve more consideration than they have received to date in the GIPSA analysis. Third, the ZS model explicitly incorporates the spatial dimension of cattle procurement, a dimension that has not been given much consideration in the GIPSA study.[9]

Conclusions and Recommendations

The data gathering component of the GIPSA investigation has been very strong. The transactions data generated and summarized provide a very comprehensive perspective on this market. The feedlot manager interviews and the information collected on marketing agreement contracts are a useful complement to the data itself. The main additional data item that could be useful is information on packers' processing costs.

Professors Azzam and Schroeter are well-qualified to analyze and interpret the data. They have produced convincing evidence of an inverse relationship between the volume of captive supply deliveries and the spot market price. Their conceptual explanation for this

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[7]The Zhang-Sexton model assumes a pricing arrangement in both the cash and contract market where feeders bear the costs of hauling cattle to the processing plant. This modelling choice arose in part due to some initial confusion on our part as to the actual arrangements in the Panhandle. In other work on oligopsony spatial markets, we refer to arrangements wherein farmers bear costs of shipping as FOB pricing arrangements. Subsequent discussions with GIPSA personnel have revealed that packers bear the shipping costs for most cash market transactions in the Panhandle, an arrangement we would call uniform-delivered pricing, but, instead, is called FOB pricing in the GIPSA investigation. Panhandle feeders generally bear the shipping costs under marketing agreement contracts. Our model thus does not fully reflect pricing arrangements in the Panhandle. We believe, however, that the basic economic incentives the model illustrates are robust to alternative pricing arrangements.

[8]Under the ZS model, packers seek captive supply contracts in the region near their procurement market boundaries. This issue could be investigated with the data that GIPSA has collected. Notable also is that the feedlot manager interviews conducted by GIPSA generally do not reveal coercion on the part of packers to sign particular feeders to captive supply contracts. A literal interpretation of the ZS model would involve pressuring feeders near procurement boundaries to sign contracts.

[9]Indeed, GIPSA, in its own review comments to SA, raise the question of whether spatial aspects of the market might contribute to explaining various of the empirical phenomena noted by SA.

phenomenon is plausible but not necessarily convincing. Additional econometric analysis on the more general question of the incidence of packer oligopsony power in this market would be useful. Such an analysis would be facilitated by information on packer processing costs, but might be possible without it by using various benchmark data in lieu of processing costs.

Because empirical support for the SA explanation for the captive supply - spot price correlation is tenuous at best, additional investigation is warranted. Two avenues to explore were discussed here. One is the bidding process, another is the spatial dimensions of the market. Conceptual analysis of the bidding process should evolve within an auction theory framework. Empirical analysis will be difficult because the data reveal only winning bids, not numbers of active bidders. Experimental economics is one possible avenue to understanding the relationship between captive supplies and the bidding process. Ward et al. represents an attempt in this direction.

The second avenue involves equilibrium modelling of packer behavior in a setting where the decision to offer captive supply contracts is endogenous. The two-stage spatial model by Zhang and Sexton illustrates this type of approach and demonstrates that captive supply contracts can be used to manipulate the cash market. The GIPSA data would enable at least some crude testing of the Zhang-Sexton model. For example, is there a particular spatial distribution to the feeders who have captive supply contracts, or are they distributed randomly through the Panhandle region?

References

Alchian, A.A. "Information, Martingales, and Prices." *Swedish Journal of Economics* 76(1974):3-11.

Ward, C. "Marketing Agreement Impacts in an Experimental Market for Fed Cattle." *American Journal of Agricultural Economics*, in press.

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May 13, 1999

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Dear Gerry:

Enclosed is an expanded and much improved version of a paper on captive supplies by Mingxia Zhang and myself. Recall that I included a preliminary version of this paper with my report on the GIPSA study of procurement practices in the Panhandle region. If possible, please substitute this version for the earlier one.

Sincerely,

Richard J. Sexton
Professor

Captive Supplies and the Cash Market Price: A Spatial Markets Approach

Mingxia Zhang
Richard J. Sexton

Department of Agricultural and Resource Economics
University of California, Davis

May 5, 1999

Captive Supplies and the Cash Market Price:

A Spatial Markets Approach

Exclusive contracts (often called "captive supplies") between processors and farmers are an increasingly important feature of modern agriculture.[1] These contracts often cause concern among producers and their advocates. A number of markets feature both spot transactions and contracts, and a key worry is that captive supplies might be used as a tool to depress the spot market price and raise processor profits. This issue has attracted particular attention in the livestock sector where several empirical studies have documented an inverse relationship between the spot market price and the incidence of exclusive contracts in a region.[2] This empirical regularity represents something of a puzzle. Explanations to date have tended to suggest that the relationship is not causal. For example, Schroeter and Azzam argue that the relationship may be a product of packers' and feeders' inventory management activities. In this paper, we use spatial modelling to show that processors can use captive supply contracts to manipulate the cash market price in some market settings.

Concern that captive supply contracts were being used to the detriment of farmers was one factor that motivated Congress to order the U.S. Department of Agriculture to study rising concentration in the red meat packing industry (USDA 1996). A current USDA investigation focuses specifically on fed cattle procurement practices in the Texas Panhandle region. The impact

[1] Frank and Henderson (1992) and Henderson (1994) report estimated shares of farm-processor output marketed through vertical integration and various forms of contract production for major U.S. food industries. To gauge the growth in vertical control in U.S. agriculture, these estimates can be compared to those reported for 1960 and 1970 by Mighell and Hoofnagle (1972).

[2] Examples of this research include Elam (1992), Schroeder *et al.* (1993), Ward, Koontz, and Schroeder (1998), and Schroeter and Azzam (1998).

of captive supplies has considerable policy relevance because the Secretary of Agriculture is authorized under the Packers & Stockyards Act to insure competition and fair trade practices in the livestock sector, a mandate that exceeds the Government's authority to intervene generally in markets under the antitrust laws.

Ward, Koontz, and Schroeder (1998) characterize the effect of captive supplies on the spot market in terms of leftward shifts in both supply and demand, noting correctly that the net effect on price is ambiguous and depends upon the functional forms of demand and supply. However, the competitive markets paradigm underlying this type of analysis may not be appropriate in many agricultural product procurement markets, including livestock. Indeed, the competitive impacts of rising concentration in meatpacking has been the focus of several recent studies of the industry including the aforementioned USDA investigation—see Azzam and Anderson (1996) for a survey of this literature.

Love and Burton (1997) and Azzam (1998) have studied economic aspects of captive supplies in beef packing using models that do allow for imperfect competition. Following Perry (1978), Love and Burton use a model of a dominant packing firm with a competitive fringe to show that the dominant firm has incentive to integrate upstream into cattle feeding to reduce efficiency losses caused by its exploitation of monopsony power. The open-market price is affected as a consequence of this behavior, but price may rise or fall depending upon how integration affects the residual elasticity of raw product supply. Azzam does not offer an explicit motivation for exclusive contracts. Rather, he uses an equilibrium displacement model of an industry to derive an expression for the elasticity of the open-market price with respect to the degree of processor upstream integration. Again, the sign of this expression is ambiguous, and

Azzam argues that a negative relationship between the open-market price and packer integration may not be a consequence of packer market power.

Our study is quite distinct from the prior work.[3] We develop a model of duopsony within a spatial markets framework to show that exclusive contracts can be used in some market settings to diminish competition between buyers and, hence, represent a device to enhance oligopsony coordination. Thus the motivation for captive supply contracts in our model is to manipulate the cash market price. The implications for competition policy are, accordingly, quite different from the prior analyses.

The Basic Model

Space is important in many agricultural raw product markets due to bulkiness and perishability and, hence, high costs of transporting the farm product. For purposes of exposition we develop the spatial model in the context of cattle feeders selling fed cattle to beef packing plants, although the analysis applies generally to any farm product market characterized by few buyers, spatially dispersed production, and relatively expensive transportation.

Consider two beef packers, A and B, located at the end points of a line with unit length. Cattle producers are located continuously along the line with uniform density $D = 1$.[4] Each producer has an identical supply function of the form $q(w(r)) = w(r)$, where q is production of fed cattle, r is the producer's distance from the processor and w(r) is the net price the producer

[3] Most prior research on exclusive or "captive" contracts in the general economics literature has emphasized their use by monopoly firms as a possible deterrent to entry. Recent contributions to this literature include Aghion and Bolton (1987). Rasmusen, Ramseyer, and Wiley (1991), Innes and Sexton (1994), and Stefanadis (1998).
[4] This basic model formulation is rather standard in the literature on spatial economics. See Greenhut, Norman, and Hung (1987) for a general overview.

receives at the farm gate.[5] A beef-packer converts q into a finished product (e.g., boxed beef), g, according to a fixed proportions production function, $g = \min\{q/\lambda, h(\mathbf{Z})\}$, where $\mathbf{Z}$ is a vector of processing inputs, and $\lambda = q/g$ is the fixed conversion factor between raw and processed product. Without further loss of generality, λ can be set equal to 1.0 through choice of measurement units and, hence, q = g. The processing cost function associated with the production function is $C(q) = m(q)q + c(q)$, where m(q) is the inverse supply function facing the processing firm, and c(q) is the cost associated with the processing inputs $\mathbf{Z}$. It will be convenient to assume constant marginal processing costs and, hence, $c(q) = cq$. Further, we assume that processors are perfect competitors in the sale of the finished product and take output price, p, as given.[6] We define $\rho = p - c$ as the finished product price net of per-unit processing costs. We further set $\rho = 1$ via a normalization, so all monetary variables are measured in the units of ρ.

The cost of transporting a unit of livestock to a processing facility is s per unit of distance. We assume a FOB or mill pricing arrangement in which packers offer a plant gate price and cattle feeders are responsible for all costs of shipping their livestock to the processing plant. The most common alternative to FOB pricing is uniform delivered (UD) pricing wherein the processor offers the same net price to all producers and bears nominally all shipping costs. The method of pricing used in practice is often not transparent. For example, in the beef industry it is rather common for packers to arrange for transportation, suggesting a UD pricing arrangement. However, packers also usually bid a unique price at each feedlot, so it is quite conceivable that

[5] This assumption implies that farm supply intersects the origin and, thus, is unitary elastic everywhere. Although this assumption comes at some cost in terms of generality, it markedly simplifies the exposition. See Zhang and Sexton (1999) for further discussion.

[6] This assumption is consistent with the notion that raw product markets are local or regional in geographic scope whereas processed product markets are often national or international. Hence, competition in processed food products will often be more intense than competition for the raw product inputs. See Rogers and Sexton (1994) and Azzam and Anderson (1996) for further discussion.

packers adjust their bids in consideration of shipping costs, causing the pricing arrangement to be FOB. We focus here on FOB pricing because the analysis is much simpler than for UD pricing.[7] The basic economic motivations at work in our analysis are present under either pricing arrangement.

Zhang and Sexton (1999) show that the importance of space in a duopsony market is measured by the ratio of the per-unit transportation cost multiplied by the distance separating processing firms (the spatial dimension) to the net value, ρ, of the finished product (the economic dimension). Given the normalizations employed here, this ratio is simply s. Given this model structure, s measures the intrinsic competitiveness of the market. For example, if $s \geq 4/3$, shipping costs are sufficiently high that the firms' desired market areas don't overlap under either FOB or UD pricing and each acts as an isolated monopsonist. As $s \rightarrow 0$, the market converges to a nonspatial duopsony, where under price setting behavior the Bertrand-Nash equilibrium involves both firms paying a farm price $m = \rho = 1$, i.e., the perfectly competitive price. Thus, the continuum of values for $s \in [0, 4/3]$ can depict the entire range of competitive outcomes from perfect competition to pure monopsony.

We first study the determinants of the duopsony FOB prices when there are no captive supplies. This equilibrium provides the benchmark to which equilibria with captive supplies will be compared. We then use multistage noncooperative game models to analyze processors' decisions to offer captive supply contracts and producers' decisions to accept or reject those contracts. The most general model would involve processors deciding first on the geographic areas in which to offer captive supply contracts and then competing in price for the captive supply

[7] The fundamental problem in a duopoly or duopsony model with UD pricing is that an equilibrium in pure strategies generally does not exist, forcing use of complicated mixed strategies. See Zhang and Sexton (1999) for further discussion.

customers. Finally, processors would compete in the spot market to procure supply not committed through captive contracts. Our experience suggests that this model in full generality is not tractable. Thus, we focus on two simplified versions of the more general model. The first version is an asymmetric model in which Firm A offers captive supply contracts but Firm B does not. In the second version both firms may offer captive supply contracts and, thus, compete in both the contract and spot market.

Results for these two models are rather similar and quite intuitive. If space, as measured by s, is sufficiently important in a market, processors can use captive supplies to, in effect, create a geographic buffer between themselves which diminishes their subsequent competition in the spot market. Thus, in these settings captive supplies represent a way to manipulate the spot market. However, if space is not important (s is small), captive supply regions do not represent an effective barrier to competition because processors have incentives to "jump" across the region of captive supplies and compete to procure product on both sides of the captive supply area.

Duopsony Price Competition without Captive Supplies

Firm A offers a mill price m_A and Firm B offers a mill price m_B at their factory gates respectively and producers are responsible for the shipping cost. A producer located at distance r from a plant receives a net price $w(r) = m - sr$. When $s \geq 4/3$, each firm operates as an isolated monopsonist, sets the monopsony price $m_A^* = m_B^* = 2/3$, and serves market radius 2/3s (Zhang, 1997). When $s < 4/3$, firms face competition from each other and the market boundary, R_A, between A and B is determined by the condition:

(1) $m_A - sR_A = m_B - s(1 - R_A)$.

This condition can be rewritten as:

$$(1') \qquad R_A = \frac{m_A - m_B + s}{2s}.$$

The duopsony market is illustrated in Figure 1.

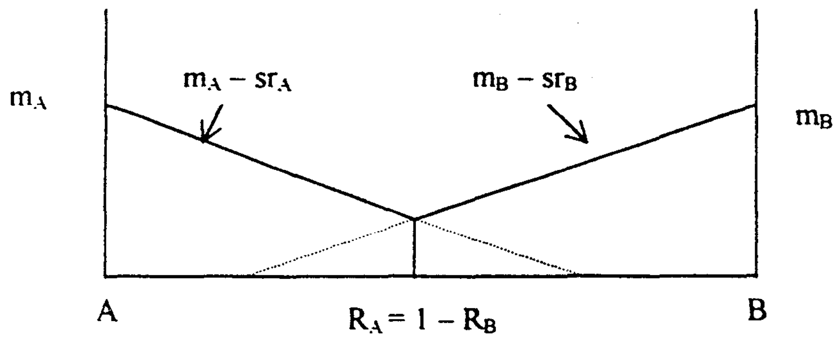

Figure 1: Duopsony FOB Price Competition without Captive Supplies

The firms' profit functions are:

$$(2) \qquad \Pi_A = (1 - m_A)\int_0^{R_A} (m_A - sr)dr = \frac{(1 - m_A)(3m_A + m_B - s)(m_A - m_B + s)}{8s}.$$

$$(3) \qquad \Pi_B = (1 - m_B)\int_0^{1-R_A} (m_B - sr)dr = \frac{(1 - m_B)(3m_B + m_A - s)(m_B - m_A + s)}{8s}.$$

The first-order conditions to maximize Π_A with respect to m_A and Π_B with respect to m_B can be solved to obtain Firm A's and Firm B's price reaction functions. Solving the two reaction functions simultaneously, we obtain the Nash-Bertrand equilibrium FOB prices without captive supplies as follows:

$$(4) \qquad m^*_{A0}(s) = m^*_{B0}(s) = m^*_0(s) = \frac{1 - 1.5s + \sqrt{1 - s + 3.25s^2}}{2},$$

where the subscript "0" denotes the FOB price solution without captive supplies. Each firm serves half the market ($R_A = ½$) in this equilibrium. Figure 2 illustrates m^*_0.

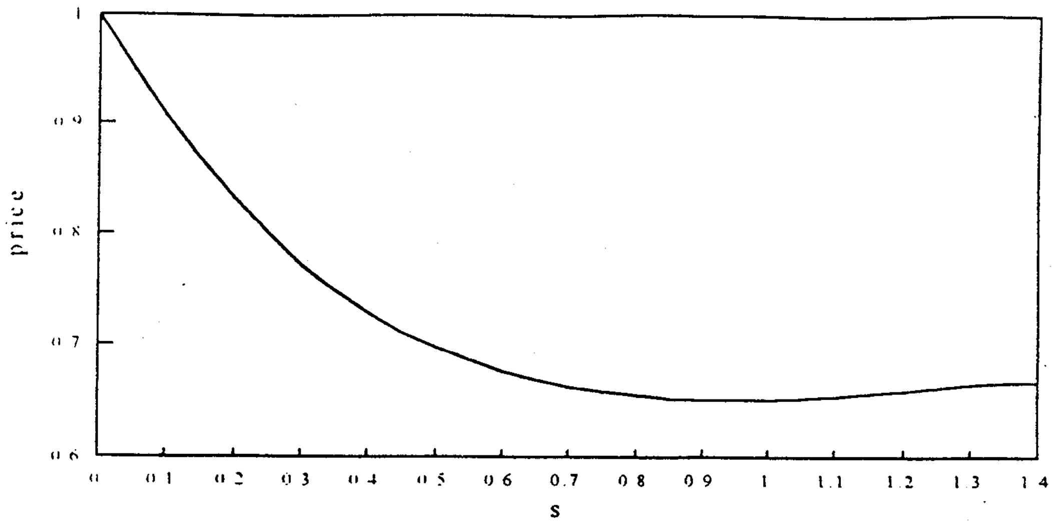

Figure 2: Optimal Duopsony FOB Prices

The equilibrium price in this model is the outcome of two offsetting factors. One factor is the price a firm would pay if it were a monopsonist operating with a fixed market radius R = ½. This price is an increasing function of s. That is, the firm rationally absorbs part of the increased shipping costs represented by higher values of s. The second factor is the effect of competition on price. Larger s diminishes competition between the firms, promoting a lower farm price. As figure 2 illustrates, this latter effect dominates over a range of values for s, but eventually the former effect dominates, with price rising to the monopsony level $m_0^* = 2/3$ for $s \geq 4/3$.

A Two-Stage Game Approach to Captive Supplies

We study a two-stage model of captive supplies where Firm A uses captive supplies but Firm B does not. This outcome might emerge, for example, in a market where one firm acts as a leader and unilaterally offers captive supply contracts. In stage 1, Firm A chooses R_c, the left boundary to its captive supply region. We assume the right boundary is fixed at 0.5, the geographic midpoint of the market, so the captive supply region, denoted as d_c is $[R_c, 0.5]$. Figure 3 illustrates the model. We assume that Firm A's contract is of the form $m_c = \max\{m_A, m_B\}$. In other words, Firm A offers to pay potential captive supply customers the maximum of its price or Firm B's price in the cash market.[8] A producer offered a captive supply contract in stage 1 must decide whether to ACCEPT the offer or REJECT it, where rejection implies that the producer elects to sell in the spot market. In stage 2, firms A and B decide on spot market prices m_A and m_B to maximize their profits, taking as given any captive supply contracts signed in stage 1. The sequential structure of the game corresponds with the way captive supplies are used in reality in that the captive supply contracts are always arranged prior to any transactions occurring in the spot market. We focus on markets where $s < 4/3$, i.e., markets that feature active duopsony competition in the absence of captive supply contracts.[9] We solve the two-stage game by backward induction, beginning first with the solution to the stage 2 price setting subgame.

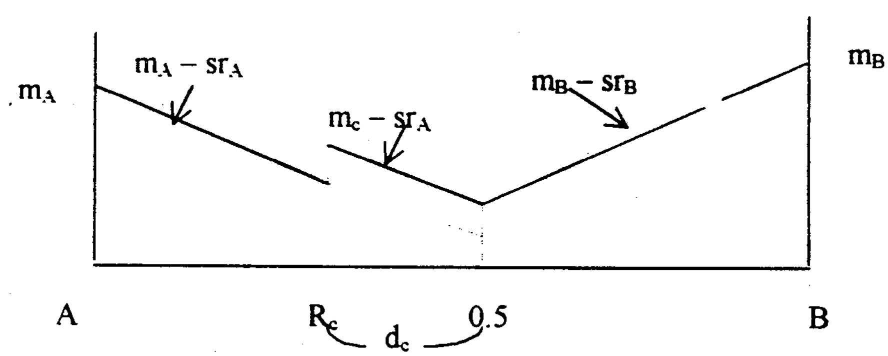

Figure 3: An Asymmetric Model of Captive Supplies

[8] This simple contract design is compatible with many of the marketing agreement contracts used in cattle procurement. These contracts often use a base price that is pegged to the price in the spot market during the delivery week. Actual contracts also specify premiums and discounts based on quality considerations, a factor that is not present in this model. Our goal is to show that exclusive contracts can be used to manipulate the spot market price and, accordingly, we don't worry especially about designing a contract that is in some sense "optimal" from a packer's perspective. The form of the contract specified here facilitates analysis of a producer's choice whether to ACCEPT or REJECT the contract.

[9] It is easy to show that the incentives to offer captive supply contracts that we demonstrate in this paper for duopsony also apply to the monopsony case.

Solution to Stage 2

In stage 2, A and B set prices m_A and m_B, taking as given the captive supply region, if any, established in stage 1. In seeking a Bertrand-Nash equilibrium to this subgame, two possibilities are evident: both firms can operate exclusively within the boundary created by the captive supply region ($[0, 0.5 - d_c)$ for firm A and $(0.5, 1]$ for firm B) or either can elect to "jump" the boundary and attempt to procure product in the region of the rival firm's location. We first establish that such boundary jumping behavior cannot be part of a Nash equilibrium set of pure price strategies.

Lemma 1: *For any captive supply region of positive measure (i.e., $d_c > 0$) prices that enable either firm to jump the boundary created by the captive supply region cannot constitute a pure strategy Nash equilibrium to the stage 2 subgame.*

Proof of the lemma relies upon the observation that location in the presence of costly transportation gives either firm a natural advantage in procuring supply from its "half" of the market. Given a value, m_A^1, for m_A, if it is profitable for Firm B to offer a price sufficiently above m_A^1 that some producers located in the region $[0, 0.5 - d_c)$ are willing to incur the higher costs of shipping product to B, then it is necessarily true that it is profitable for A to offer a higher price than m_A^1 so as to retain those producers. A similar argument applies to possible boundary jumping behavior by Firm A. Thus, any price pair that results in boundary jumping by either firm cannot be part of a pure strategy Nash equilibrium.

We focus, therefore, on strategies that involve each firm procuring supply from only those producers located on its side of the captive supply region. Specifically, we derive the simple monopsony optima for each firm and then determine the values for s for which these prices are robust to potential boundary jumping strategies. The firms profit functions as monopsonists in their spot market areas are:

(5) $$\Pi_A^{nc} = (1-m_A)\int_0^{0.5-d_c}(m_A - sr)dr = \frac{(1-m_A)}{2}(0.5-d_c)(2m_A - 0.5s + sd_c),$$

(6) $$\Pi_B = (1-m_B)\int_0^{0.5}(m_B - sr)dr = \frac{(1-m_B)}{2}(m_B - 0.25s).$$

From the first order conditions we obtain Firm A's and Firm B's optimal prices:

(7) $$m_A^*(d_c, s) = \frac{1}{2} + \frac{s}{8} - \frac{sd_c}{4},$$

(8) $$m_B^*(s) = \frac{1}{2} + \frac{s}{8}.$$

Thus in stage 2, $m_B^* > m_A^*$. Notice in particular that m_A^* is a decreasing function of the magnitude, d_c, of A's captive supply region because A's monopsony spot price is an increasing function of the spot market area that A serves. The reason is that, as the spot market area increases, the average shipping costs incurred by A's customers rise. Firm A rationally absorbs a portion of these costs in setting m_A^*.

The firms' profits from their non-captive supply regions are:

(9) $$\Pi_A^*(d_c, s) = \frac{1}{128}(1-2d_c)[4 - s(1-2d_c)]^2,$$

(10) $$\Pi_B^*(s) = \frac{1}{128}(4-s)^2.$$

Solution to Stage 1

In stage 1, Firm A's total profit, Π_A^T, from both the non-captive supply area and the captive supply area is

(11) $$\Pi_A^T = \Pi_A^* + \Pi_A^{cap} = (1-m_A^*)\int_0^{0.5-d_c}(m_A^* - sr)dr + (1-m_c)\int_{0.5-d_c}^{0.5}(m_c - sr)dr,$$

where m_A^* is Firm A's optimal mill price from stage 2 as specified in (7), and $m_c = \max\{m_A^*, m_B^*\} = m_B^*$.[10] The first term on the right-hand side is A's profit from spot market transactions, and the second term is profit from captive supplies. Substituting m_A^* and m_B^* into (11) yields:

$$(11') \quad \Pi_A^T(d_c, s) = \frac{1}{128}(1 - 2d_c)(4 - s + 2sd_c)^2 + \frac{d_c}{64}(4 - s)(4 - 3s + 4sd_c).$$

Maximizing (11') with respect to d_c yields the following solution:

$$(12) \quad d_c^* = \frac{1}{3}.$$

Thus in stage 1, Firm A offers captive supply contracts to the farmers located between 1/6 and ½. This result does not depend on s. Given $d_c^* = 1/3$, the firms' optimal mill prices in stage 2 are

$$(13) \quad m_A^*(s) = \frac{1}{2} + \frac{s}{24}, \qquad m_B^*(s) = \frac{1}{2} + \frac{s}{8}.$$

Firm A thus offers the captive supply contract $m_c = \max\{m_A, m_B\} = m_B^*$ to producers in the interval [1/6, ½]. Will producers in the captive supply area ACCEPT or REJECT the contracts? Given the form of the contract, these producers receive a price at least as high as those who sell in the spot market, and we assume that a producer who is indifferent will agree to sign the contract. However, rational producers must consider the effect of their actions on the market equilibrium. In other words, will a producer agree to sign the contract knowing that the aggregate effect of captive supply contracts is to depress the cash market price and make all producers, including himself, worse off than if none signed the contract?

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[10] Note, as Figure 3 illustrates, that our equilibrium prices are vulnerable to producer arbitrage in the region near the contract market boundary, R_c. Producers to the immediate left of R_c have incentive to ship product to R_c and attempt to procure the contract price $m_B^* > m_A^*$. We don't concern ourselves with arbitrage because the contracts can be readily designed to surmount it. For example, discriminatory contracts can be used to reduce the contract price near R_c, or the contracts could be written to limit each producer's supply to $q^* = q(m_B^*)$.

Rasmusen, Ramseyer, and Wiley (RRW 1991) answer this question affirmatively in an analysis of exclusionary contracts designed to deter entry in a monopoly market. The logic they develop to show that rational agents will sign exclusive contracts that are mutually detrimental also applies here. In our proposed equilibrium, producers in the contract area receive $m_c = \max\{ m_A^*, m_B^* \} = m_B^*$. If no exclusive contracts were signed, from (4) these producers would receive $m_0^* > m_B^*$. Thus, if the producers in the captive supply region were able to coordinate their actions, they could benefit by mutually refusing to sign the captive supply contracts. It is precisely the inability to coordinate that RRW demonstrate enables the excluding firm to secure the customers' acceptance of the contracts. In particular, note that Firm A *could* pay the captive supply customers $m_0^* + \varepsilon$ if necessary, where ϵ is a small "signing bonus" and still benefit from offering captive supply contracts because of the lower price it is able to pay its spot market customers as a consequence. Thus, any producer in the proposed captive supply region knows Firm A can guarantee acceptance of its captive supply contracts by offering $m_0^* + \varepsilon$, and, therefore, that the captive supply arrangement will succeed. Unilateral refusal by a producer to accept his contract cannot affect the ultimate success of the arrangement. Thus, as long as the producer is offered at least as much as he can receive in the spot market in the equilibrium with captive supplies, his equilibrium strategy is to ACCEPT the contract.[11] In essence, the knowledge that Firm A has the economic incentive to implement his preferred captive supply region enables A to secure captive supply contracts at a minimum cost.

[11] This argument applies regardless of whether producers decide sequentially or simultaneously on acceptance or rejection (RRW, 1991).

Thus, the candidate subgame perfect equilibrium to this two-stage game involves Firm A offering captive supply contracts in the region [1/6, ½], and producers in that region accepting the captive supply contract that offers $m_c = \max\{m_A^*, m_B^*\}$. The equilibrium stage 2 spot market prices in (13) represent the monopsony solutions given the captive supply region set in place in stage 1. The remaining task is to investigate the set of values, if any, for s for which this solution is sustainable. Specifically, we need to determine the values of s for which the stage 2 monopsony prices do not invite "boundary jumping" wherein at least one of the firms competes to procure product on both sides of the captive supply area. We must check sequentially whether, given m_A^*, Firm B wants to procure product in the region [0,1/6), and, given m_B^*, whether Firm A wants to procure product in the region (1/2, 1].

Given $m_A^* = 0.5 + s/24$, we check first whether it is profitable for Firm B to jump to Firm A's spot market area. Let Π_B^j denote B's profit from pursuing a boundary jumping strategy. B's problem is to choose m_B to maximize Π_B^j:

$$\text{(15)} \qquad \max\{m_B\}\, \Pi_B^j = (1-m_B)\int_0^{.5}(m_B - sr)dr + (1-m_B)\int_{5/6}^{1-R_A}(m_B - sr)dr,$$

where

$$R_A = \frac{m_A^* - m_B + s}{2s} = \frac{1}{4s} + \frac{25}{48} - \frac{m_B}{2s},$$

given $m_A^* = 0.5 + s/24$. The solution to (15) is

$$\text{(16)} \qquad m_B^j(s) = \frac{32 + 6s + \sqrt{592 - 600s - 459s^2}}{72},$$

and $\Pi_B^{j*} = \Pi_B^j(m_B^j(s))$ represents the maximized profit from boundary jumping.

Because B can pursue either the boundary jumping or the monopsony strategy, we express B's overall profit as

$$\Pi_B^{o} = \max\{\Pi_B^*(s), \Pi_B^{j*}(s)\},$$

where $\Pi_B^*(s)$ is defined in (10) and represents the maximum profit from pursuing the monopsony strategy. Comparing the two maximized profits reveals that B prefers to jump across the captive supply boundary and procure product in the region [0, 1/6) for $s < 0.2367$.

We next check Firm A's incentive to jump to B's area given $m_B^* = 0.5 + s/8$. Let Π_A^j denote Firm A's profit from boundary jumping. A's problem under a boundary jumping strategy is to choose m_A to maximize Π_A^j:

(18) $$\max\{m_A\}\, \Pi_A^j = (1 - m_A)\int_0^{R_A}(m_A - sr)dr,$$

where

$$R_A = \frac{m_A - m_B^* + s}{2s} = \frac{m_A - 0.5 + 0.75s}{2s},$$

given $m_B^* = 1/2 + s/8$. Notice that for Firm A to procure supply from the region (0.5, 1] in the spot market, A must set its price above m_B^*. Thus, A's price in the contract market is $m_c = \max\{m_A^*, m_B^*\} = m_A^*$, and A's contract and spot price are identical, leading to equation (18). The solution to the problem in (18) is

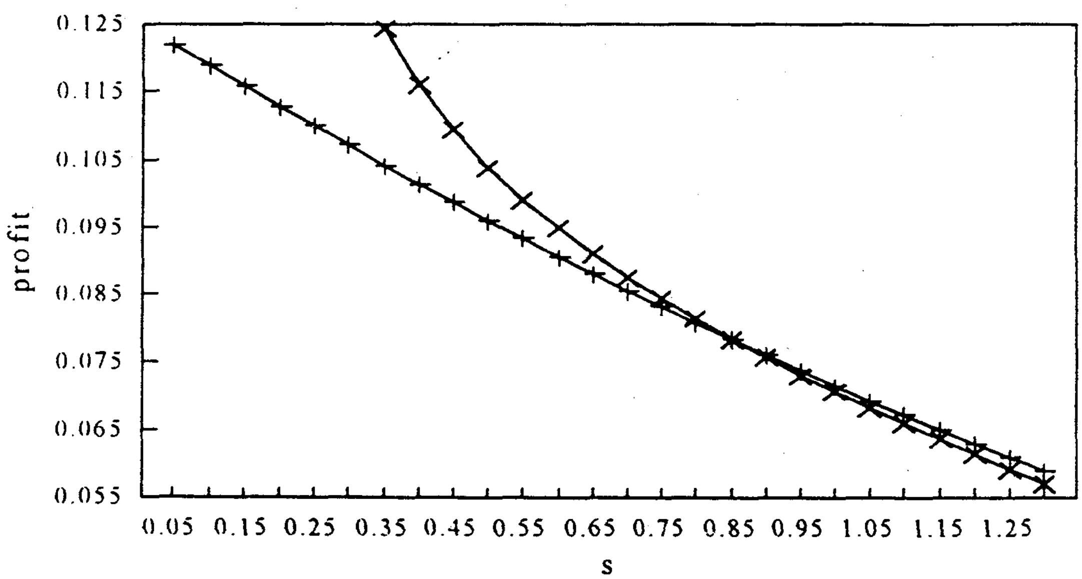
(19) $$m_A^j(s) = \frac{32 - 14s + \sqrt{637s^2 - 392s + 592}}{72},$$

and $\Pi_A^{j*} = \Pi_A^j(m_A^j(s))$ represents the maximized profits from boundary jumping.

Because A can pursue either the boundary jumping or the monopsony strategy, we express A's overall profit as

$$\Pi_A^u = \max\{\Pi_A^T(d_c^*, s), \Pi_A^{J*}(s)\},$$

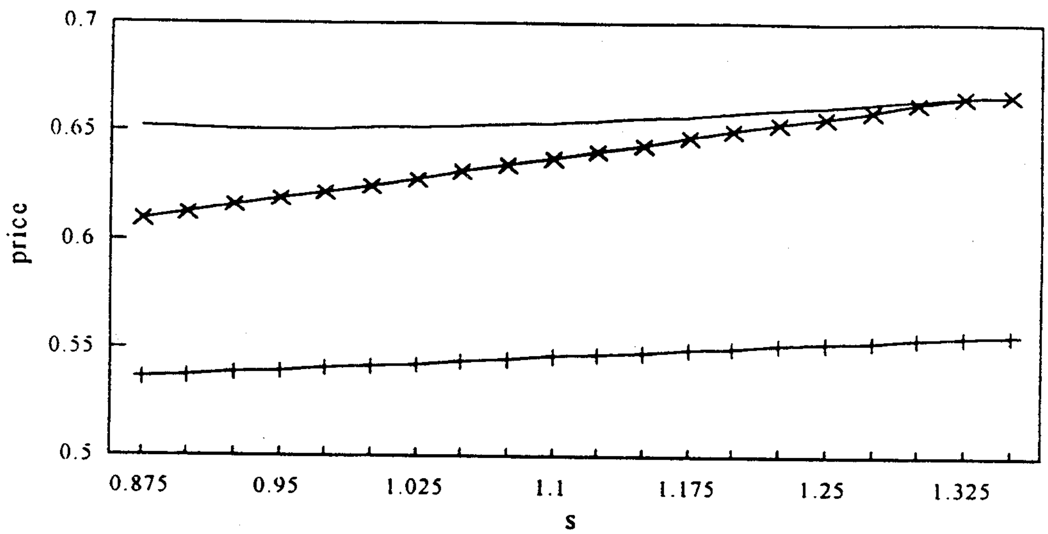
where $\Pi_A^T(d_c^*, s)$ is found by substituting $d_c^* = 1/3$ into (11') and represents the maximum profit from pursuing the monopsony strategy. Comparing the two maximized profits as illustrated in Figure 4 reveals that A prefers a boundary jumping strategy, given m_B^*, whenever $s < 0.8665$. The intuition in either boundary jumping case is that a captive supply region represents an ineffective barrier to competition when s is small because firms are readily able and willing to procure product across a large geographic area.



Legend: + Π_A^T, × Π_A^{J*}

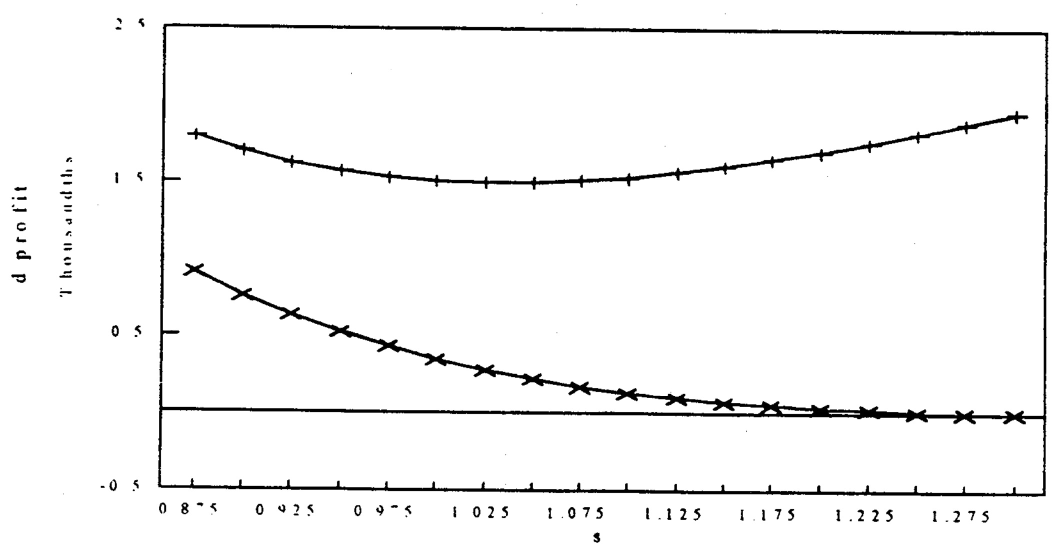
Figure 4: Firm A's Profit under Monopsony Strategies and Boundary Jumping

Thus, the solution for d_c, m_A, and m_B given in (12) and (13) is robust to boundary jumping strategies by either firm for $s \geq 0.8665$ and, therefore, this solution represents a subgame perfect equilibrium within this range of space. As Figure 5 illustrates, both Firm A and B offer a lower price in the spot market than the duopsony price without captive supplies. Both firms make at least as much profit in this captive supply setting as in the duopsony setting without captive supplies as illustrated in Figure 6. Thus in markets where space is of sufficient importance, processors can use selective captive supply contracts to diminish the spot market price and increase profits at producers' expense.



Legend: – m_0^*, + m_A^*, × m_B^*

Figure 5: Optimal FOB Prices with Captive supplies



Legend: + $(\Pi_A^* - \Pi_0^*)$, × $(\Pi_B^* - \Pi_0^*)$

Figure 6: Differences between Profits under Captive Supplies and Duopsony

For $s < 0.8665$, boundary jumping defeats an attempt to implement the monopsony solution given in (12), (13). However, the boundary jumping prices given in (16) and (19) do not themselves represent Nash equilibrium strategies. Rather, they respectively represent price strategies B and A would choose in response to the rival firm's monopsony spot prices given in (13) for the indicated ranges of s. The monopsony price in (13) is not optimal if it is vulnerable to boundary jumping strategies, i.e., the combination of the monopsony price for firm i and a boundary-jumping price for firm j do not constitute a Nash equilibrium to the stage 2 pricing game.

The problem is that the firms' profit functions, as expressed in (17) for A and (14) for B, are discontinuous in m_A and m_B, respectively, for values of s that invite boundary jumping at the monopsony prices. In general, discontinuity in a player's payoff as a function of the player's choice variable causes a problem of nonexistence of equilibrium in pure strategies. An equilibrium in mixed strategies does exist, however (Dasgupta and Maskin). In contrast to a pure price strategy, which is expressed in terms of a rule such as (13) for choosing price, a mixed strategy is expressed in terms of a probability distribution function for price, i.e., a probability rule for choosing m_A. We do not attempt to characterize the mixed strategy equilibria in this paper.

A Three-Stage Game Model of Captive Supplies

In the preceding model, a leader firm moved unilaterally to offer captive supply contracts. It will also be interesting to consider a model where the firms compete both in the contract market and in the cash market. Thus, in this section we consider a model where both firms may offer captive supply contracts. In stage 1, the firms decide on the market area in which to offer captive supply contracts. We assume this region $[k, 1 - k]$ is symmetric around the midpoint of the market. In stage 2, the firms compete to offer captive supply contracts in this region. The market boundary between firms A and B in the captive supply region is found where the firms' net contract prices are equal: $R_A = (m_{Ac} - m_{Bc} + s)/2s$. In stage 3, Firms A and B, respectively, offer monopsony spot prices for farmers in the intervals [0, k) and (1 − k, 1] that are not served by captive supply contracts. Figure 7 illustrates the market set up.

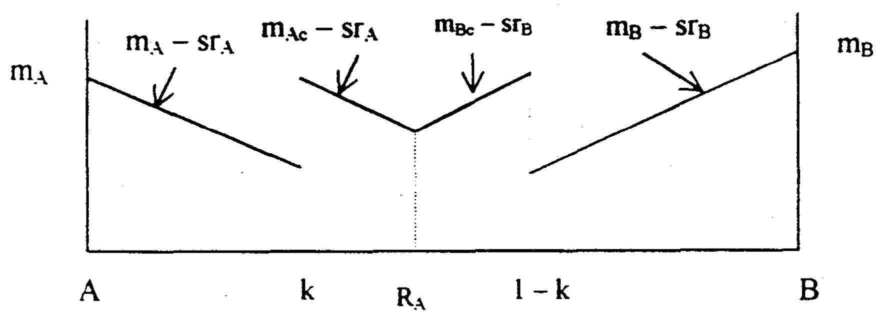


Figure 7: A Symmetric Model of Captive Supplies

Solution to Stage 3

As in the previous model, we find the monopsony solution in the spot market regions and then determine whether this solution is sustainable against any boundary jumping strategies. The firms' profit functions in the non-captive supply areas are as follows:

(20) $\Pi_A^* = (1 - m_A)\int_0^k (m_A - sr)dr = \frac{k}{2}(1 - m_A)(2m_A - sk)$.

(21) $\Pi_B^* = (1 - m_B)\int_0^k (m_B - sr)dr = \frac{k}{2}(1 - m_B)(2m_B - sk)$.

Profit maximization yields the following monopsony solutions for the spot market price:

(22) $m_A^*(s) = m_B^*(s) = \frac{1}{2} + \frac{sk}{4}$.

Notice again that the larger is the captive supply region (i.e., the smaller is k), the lower is the resulting spot market price. As the spot market region increases, each firm rationally increases its monopsony price to partially absorb the higher costs of shipping incurred by more distant producers.

Solution to Stage 2

The firms compete in prices m_{Ac} and m_{Bc} to procure captive supply contracts taking as given the contract market area [k, 1 – k]. The firms' profits from offering captive supplies are as follows:

$$(23)\quad \Pi_A^{cap} = (1 - m_{Ac})\int_k^{R_A}(m_{Ac} - sr)dr,$$

$$(24)\quad \Pi_B^{cap} = (1 - m_{Bc})\int_k^{1-R_A}(m_{Bc} - sr)dr,$$

Where $R_A = (m_{Ac} - m_{Bc} + s)/2s$. Maximizing (23) and (24) with respect to m_{Ac} and m_{Bc} respectively yields the reaction functions that can be solved to yield the Bertrand-Nash equilibrium contract prices to stage 2:

$$(25)\quad m_{Ac}^{*}(s,k) = m_{Bc}^{*}(s,k) = \frac{1 - 1.5s + 4sk + \sqrt{1 - s + 3.25s^2 + 12s^2k(k-1)}}{2}.$$

The captive supply contract prices $m_{Ac}^{*} = m_{Bc}^{*}$ are determined identically to the pure duopsony price m_0^{*} obtained in (4) except that competition for captive supplies occurs in the concentrated area [k, 1 – k] rather than over the entire market, [0, 1]. For example, when k = 0, equations (4) and (25) are equivalent. The competition for captive supplies is, accordingly, more intense and the contract prices are higher than both the pure duopsony price and the spot market contract price for all k > 0 — see figure 8. Thus, it follows immediately that all producers offered captive supply contracts in stage 2 will choose to ACCEPT the offer.

Solution to Stage 1

In stage 1, we assume Firm A chooses the lower boundary, k_A, of the captive supply region and Firm B chooses the upper boundary $1 - k_B$.[12] Each firm makes this decision to maximize his total profit from both the non-captive and the captive areas, taking into account the ensuing competition in stages 2 and 3. Because the firms are symmetric, we set $k_A = k_B = k$, and focus on Firm A's choice. A's stage 1 optimization problem is as follows:

$$(26)\quad \max\{k\}\quad \Pi_A^T = \Pi_A^* + \Pi_A^{cap} = (1 - m_A^*)\int_0^k (m_A^* - sr)dr + (1 - m_{Ac}^*)\int_k^{R_A} (m_{Ac}^* - sr)dr$$
$$= \frac{k}{16}(2 - sk)^2 + \frac{(1 - m_{Ac}^*)}{8}(1 - 2k)(4m_{Ac}^* - s - 2sk),$$

where m_{Ac}^* is given in (25). The first term in (26) is profit from the spot market, and the second term is profit from captive supplies.

The intuition is that by setting $k \in (0, 0.5)$, A creates a dual market. In the captive supply region, $[k, 1 - k]$, Firms A and B compete in price to sign producers to captive supply contracts. As noted, the contract prices in (25) are higher than the pure duopsony prices in (4). This fact, however, does not necessarily mean that profits in the captive supply region are less than profits in that region under the pure duopsony solution. The reason is that, if the buyer could price discriminate, he would prefer to offer higher prices to more distant producers to compensate partially for their higher shipping costs. For large values of s, the pure duopsony price in (4) is *less* than the price that would maximize profits considering only the producers in the captive supply region. Thus, the higher contract price and the higher production it induces can actually increase profits from serving those producers.

[12] Because competition occurs only at the midpoint, R_A, of the captive supply region (see Figure 6), this assumption seems reasonable.

Use of captive supplies also reduces competition in the spot market areas [0, k) and (1 – k, 1]. Either firm earns more profit in the spot market areas by offering the monopsony price in (22) than it earns by offering the duopsony price in (4). However, the monopsony price is not an equilibrium for all values of s because for small s, it is not sustainable in the face of boundary jumping strategies, although the boundary jumping strategies themselves cannot constitute Nash equilibria, i.e., Lemma 1 applies to this model as well.

We used simulation methods to solve (26) to find k*(s), the optimal captive supply boundary, given the stage 3 monopsony prices in (22) and the stage 2 contract prices in (25 We then must determine for each value of s, using analysis similar to that employed for the asymmetric model, whether the candidate strategies, k^*, m^*_A, and m^*_{Ac} for k, m_A, and m_{Ac}, are sustainable against boundary jumping strategies by either firm. Because the firms are symmetric in this model, we need check only Firm A's incentive to engage in boundary jumping given $k^*(s)$, m^*_{Bc}, and m^*_B. Firm A's profit maximization problem under a boundary jumping strategy is

$$(27)\quad \max\{m_A\}\quad \Pi^J_A = \Pi^{cap}_A + (1-m_A)[\int_0^k (m_A - sr)dr + \int_{1-k}^{R_A} (m_A - sr)dr],$$

where

$$R_A = \frac{m_A - m^*_B + s}{2s} = \frac{m_A - 0.5 + s(1-0.25k)}{2}.$$

The solution to (27) is:

$$m^J_A(s\,|k^*) = \frac{2(12s + 8 - 31sk^*) + \sqrt{144s^2 - 240s - 1896s^2k^* + 148 + 284sk^* + 3853s^2k^{*2}}}{36},$$

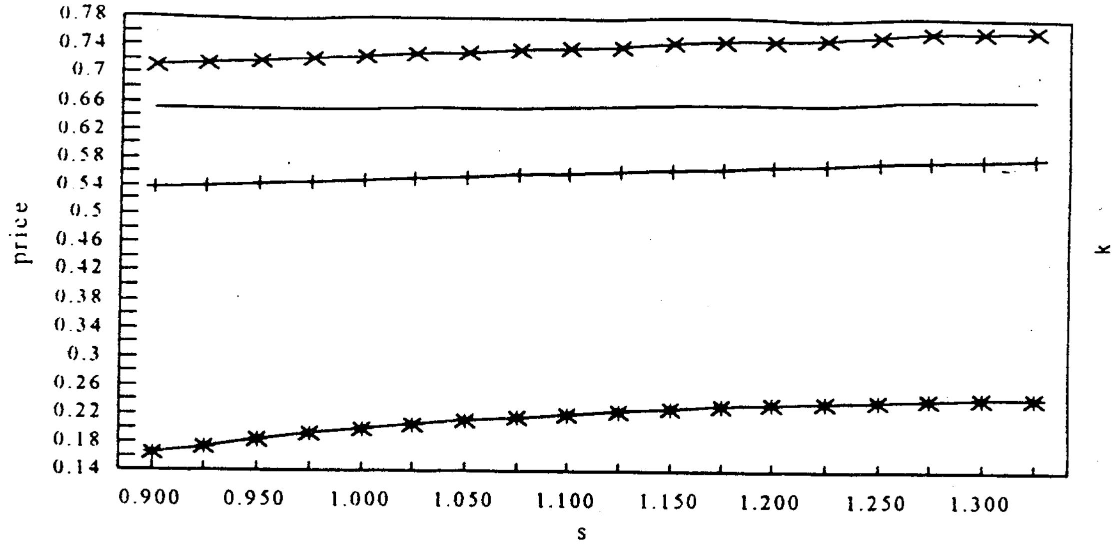
and $\Pi^{J*}_A = \Pi^J_A(m^J_A)$ represents the maximized profits from boundary jumping.

We express A's overall profit as

$$\Pi_A^{o} = \max\{\Pi_A^T(s \mid k^*), \Pi_A^{J*}(s \mid k^*)\},$$

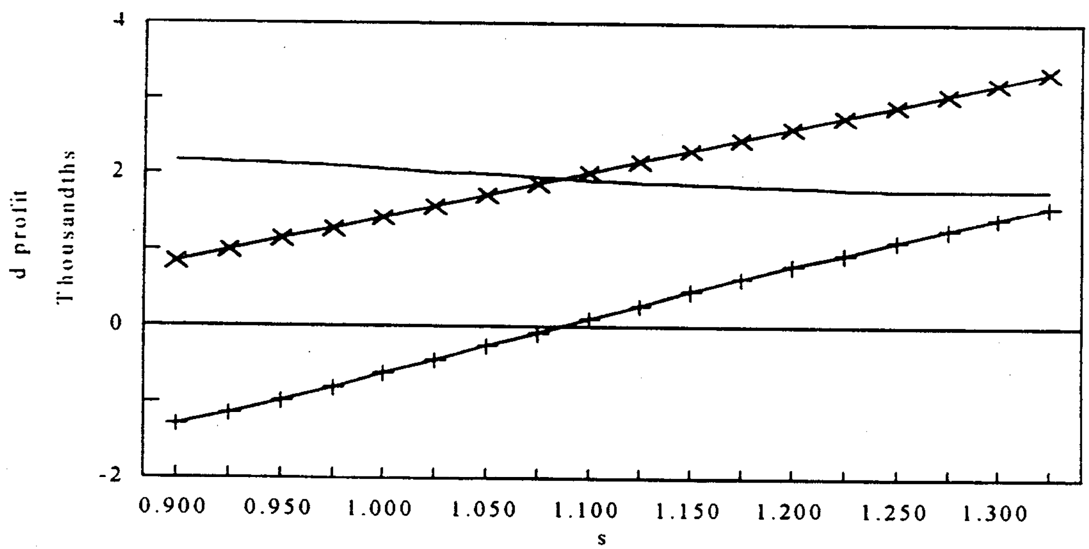
Comparison of Π_A^T and Π_A^{J*} indicates that Firm A will jump to B's market area when $s < 0.893$, given k^* and $m_B^* = ½ + sk^*/4$. Therefore the solutions for m_A^* m_B^*, $m_{Ac}^* = m_{Bc}^*$ from (22) and (25) and the simulated solution k^* for k apply only for $s \geq 0.893$. Again, when space is less important, captive supplies represent an ineffective barrier to competition.

Figure 8 illustrates the solution for the sustainable range of s, including the captive supply boundary k^*, monopsony spot price, captive supply price, and for comparison the pure duopsony price for values of s in this region. When firms compete to offer captive supply contracts, each offers the contracts over a smaller geographic area than when a leader firm unilaterally offers such contracts. Figure 9 shows the differences between a firm's profit and the duopsony profit in the intervals $[0, k^*)$, $[k^*, 0.5]$, and in total when the firms offer captive supply contracts in the range $s \in [0.893, 4/3]$. The firms always gain in the spot market region and in total from offering captive supplies. The profit differential from the spot market decreases when s increases. Firms lose in the captive supply region compared to pure duopsony for smaller values of s, but when $s > 1.088$, firms also gain in the captive supply region.



Legend: – m^*_0, + $m^*_A = m^*_B$, × $m^*_{Ac} = m^*_{Bc}$, * k^*

Figure 8: Optimal Captive Supply Prices and Boundary



— [0,k] + [k,0.5] ✳ [0,0.5]

Figure 9: Differences in Processor Profits under Captive Supplies and Pure Duopsony

Concluding Comments

Our spatial models show that processors may be able to use captive supply contracts to manipulate the cash market price to producers' detriment. This result is consistent with a stylized fact from the cattle industry that the cash price in a region is negatively correlated with the use of captive supply arrangements in the region. Prior analyses of this phenomenon have not offered convincing explanations and, for the most part, have emphasized explanations that do not involve market manipulation. We do not suggest that our model represents a definitive explanation for the use of captive supply contracts in farm product markets. Indeed such contracts may be motivated by any of several efficiency considerations, including reducing the distortions due to processor monopsony power (Love and Burton, 1997), and addressing problems of adverse selection or moral hazard among producers (Katz, 1989).

However, our demonstration that captive supplies can be used in a manipulative fashion in a concentrated spatial market does emphasize that it is important for policy makers to evaluate the expanding use of captive supply arrangements in agriculture with a critical eye. The stylized models presented here emphasize that bases for concern are greatest in markets that feature high buyer concentration and shipping costs that are high relative to the net value of the finished product. In these settings captive supply regions form an effective spatial barrier between firms, enabling each to act as a monopsonist in the spot market area near his respective location.

References

Aghion, P. and P. Bolton. "Contracts as a Barrier to Entry." *American Economic Review* 77(1987): 388-401

Azzam, A. "Captive Supplies, Market Conduct, and the Open-Market Price." *American Journal of Agricultural Economics* 80(1998): 76-83.

Azzam, A. and D. Anderson. "Assessing Competition in Meatpacking: Economic History, Theory and Evidence," U.S. Department of Agriculture, GIPSA-RR 96-6, May 1996.

Dasgupta, P. and E. Maskin. "The Existence of Equilibrium in Discontinuous Economic Games, I & II: Theory and Applications," *Review of Economic Studies* 53(1986): 1-41.

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

Frank, S. and D.R. Henderson. "Transactions Costs as Determinants of Vertical Coordination in the U.S. Food Industries." *American Journal of Agricultural Economics* 74(1992): 941-50.

Greenhut, M.L., G. Norman, and C-S. Hung. *The Economics of Imperfect Competition: A Spatial Approach*, Cambridge: Cambridge University Press, 1987.

Henderson, D.R. "Measuring and Assessing Vertical Ties in the Agro-Food System." *Canadian Journal of Agricultural Economics* 42(1994): 549-60.

Innes, R. and R.J. Sexton. "Strategic Buyers and Exclusionary Contracts." *American Economic Review* 84(1994): 566-84.

Katz, M. "Vertical Contractual Relations," in R. Schmalensee and R. Willig (eds.) *Handbook of Industrial Organization*, Vol. I, Amsterdam: North Holland, 1989.

Love, H.A. and D.M. Burton. "A Rationale for Captive Supplies," in J.A. Caswell and R.W. Cotterill, (eds.), *Strategy and Policy in the Food System: Emerging Issues*, University of Connecticut, Food Marketing Policy Center, 1997.

Mighell, R.L. and W.S. Hoofnagle. "Contract Production and Vertical Integration in Farming, 1960 and 1970." USDA, ERS-479, 1972.

Perry, M.K. "Vertical Integration: The Monopsony Case." *American Economic Review* 68(1978): 561-70.

Rasmusen, Eric B., Ramseyer, J. Mark, and Wiley, John S., "Naked Exclusion," *American Economic Review* 81(1991): 1137-1145.

Rogers, R.T. and R.J. Sexton. "Assessing the Importance of Oligopsony Power in Agricultural Markets." *American Journal of Agricultural Economics* 76(1994): 1143-50.

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

Schroeter, J.R. and A. Azzam. "Captive Supplies and Spot Market Prices for Fed Cattle in the Texas Panhandle." Draft Report submitted to USDA Grain Inspection, Packers and Stockyards Administration, November 1998.

Stefanadis, C. "Selective Contracts, Foreclosure, and the Chicago School View." *Journal of Law and Economics* 41(1998): 429-50.

U.S. Department of Agriculture, Agricultural Marketing Service, "Concentration in Agriculture: A Report of the USDA Advisory Committee on Agricultural Concentration," June 1996.

Ward, C.E., S.R. Koontz, and T.C. Schroeder. "Impacts from Captive Supplies on Fed Cattle Transaction Prices." *Journal of Agricultural and Resource Economics* 23(1998): 494-514.

Zhang, M. "Three Essays on Imperfect Competition in Agricultural Markets," Ph.D. Dissertation, University of California, Davis, 1997.

Zhang, M. and R.J. Sexton. "FOB or Uniform Delivered Prices: Strategic Choice and Welfare Effects," working paper, Department of Agricultural and Resource Economics, University of California, Davis, January 1999.