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

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Exclusive contracts (often called "captive supplies") between processors and farmers are an increasingly important feature of modern agriculture. We study an interesting empirical regularity occurring in markets that feature both contract and spot exchange: the spot price is inversely related to the incidence of contract use in the market. We use a spatial model and a noncooperative game approach to show that processors can use exclusive contracts to manipulate the spot price in certain situations. Captive supplies in these settings represent geographic buffers that reduce competition among processors. However, in markets where the spatial dimension is less important, captive supplies are ineffective as barriers to competition because firms have incentive to "jump" across a captive supply region to procure the farm product.

Key words: captive supplies, duopsony, exclusive contracts, FOB price, meat packing, spatial market

Introduction

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 reduce producer profits. This issue has attracted particular attention in the cattle 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. Analyses to date have emphasized that the relationship may not be causal. For example, Ward et al. suggest the relationship may be a result of packers' and

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[1] Frank and Henderson, and Henderson 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.

[2] Studies that have documented an inverse relationship between the cash market price and magnitude of deliveries from captive supplies include Elam; Schroeder et al.; and Ward, Koontz, and Schroeder. Captive supply deliveries had an ambiguous effect on the cash price in a study by Hayenga and O'Brien. Preliminary analysis of data from an ongoing USDA study of cattle procurement in the Texas Panhandle region also indicates an inverse relationship between the cash price and packers' use of captive supplies. (Because this study is in progress, USDA is holding the details of the analysis in confidence.)

feeders' inventory management activities. In this study, we employ spatial modeling to show that processors can use captive supply contracts strategically to influence 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/Agricultural Marketing Service). A current USDA investigation focuses specifically on fed cattle procurement practices in the Texas Panhandle region. The impact of captive supplies in the livestock sector has considerable policy relevance because the Secretary of Agriculture is authorized under the Packers and Stockyards Act to ensure competition and fair trade practices in these industries, a mandate that exceeds the government's authority to intervene generally in markets under the antitrust laws.

Ward, Koontz, and Schroeder 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 have been the focus of several recent studies of the industry, including the aforementioned USDA investigation (see Azzam and Anderson for a survey of this literature).

Azzam, and Love and Burton have studied some economic aspects of captive supplies in beef packing using models that do allow for imperfect competition. Following Perry's 1978 work, 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 influence the cash market price. The implications for competition policy are, accordingly, quite different from the prior analyses.[4]

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[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; Rasmusen, Ramseyer, and Wiley; Innes and Sexton; and Stefanadis.

[4] By focusing on the use of captive supply contracts as a means to influence the spot market price, we do not mean to suggest that other factors, such as those discussed by Ward et al. and by Love and Burton, are unimportant in packers' decisions whether to offer such contracts. However, even if captive supply arrangements are implemented primarily for some other reason, our analysis shows that their presence may have the effect of reducing the spot market price.

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 $D = 1$.[5] 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 receives at the farm gate.[6] 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 thus $c(q) = cq$. Further, we assume that processors are perfect competitors in the sale of the finished product and take output price, p, as given.[7] 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 units of ρ.

The cost of transporting a unit of livestock to a processing facility is s per unit of distance. We assume an 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 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

[5] This basic model formulation is rather standard in the literature on spatial economics (see Greenhut, Norman, and Hung for a general overview).

[6] 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 for further discussion.)

[7] 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 (Rogers and Sexton). This view of the beef packing industry is generally consistent with empirical studies of market power in the industry as summarized by Azzam and Anderson. However, Hayenga, Koontz, and Schroeder argue, based on a variety of empirical tests, that regional cattle prices are closely interrelated and that "analyses of concentration in beef packing need to focus on relatively broad geographic markets."

UD pricing.[8] The basic economic motivations at work in our analysis are present under either pricing arrangement.

Zhang and Sexton show the relative importance of space in a duopsony market is determined 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 do not overlap under either FOB or UD pricing, and each acts as an isolated monopsonist.[9] As $s \to 0$, 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. Therefore, the continuum of values for $s \in [0, 4/3]$ depicts the entire range of competitive outcomes from perfect competition to pure monopsony.

We first examine 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 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 therefore compete in both the contract and spot markets.

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, in effect, to create a geographic buffer between themselves which diminishes their subsequent competition in the spot market. In these settings, captive supplies represent a way to influence 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

Firms A and B offer mill prices m_A and m_B, respectively, at their factory gates and producers are responsible for the shipping cost. A producer located at distance r from a

[8] The key 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 for further discussion).

[9] For example, an FOB-pricing firm that is a pure monopsonist—and thus is free to choose both purchase price (m) and market area (R^m)—will set $m = 2/3$ and serve market radius $R^m = 2/3s$ (Zhang). Hence, for $s \geq 4/3$, firm A's and firm B's market areas do not overlap, and each can act as a pure monopsonist. A similar result holds for the UD pricing case.

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). When $s < 4/3$, the firms face competition from each other. In this case, the market boundary (R_A) between A and B is determined by the condition:

$$m_A - sR_A = m_B - s(1 - R_A). \tag{1}$$

This condition can be rewritten as:

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

The duopsony market is illustrated in figure 1.

The respective profit functions for firms A and B are:

$$\begin{aligned} \Pi_A &= (1 - m_A)\int_0^{R_A} (m_A - sr)\,dr \\ &= \frac{(1 - m_A)(3m_A + m_B - s)(m_A - m_B + s)}{8s} \end{aligned} \tag{2}$$

and

$$\begin{aligned} \Pi_B &= (1 - m_B)\int_0^{1-R_A} (m_B - sr)\,dr \\ &= \frac{(1 - m_B)(3m_B + m_A - s)(m_B - m_A + s)}{8s}. \end{aligned} \tag{3}$$

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:

$$m_{A0}^*(s) = m_{B0}^*(s) = m_0^*(s) = \frac{1 - 1.5s + \sqrt{1 - s + 3.25s^2}}{2}, \tag{4}$$

where the subscript "0" denotes the FOB price solution without captive supplies. Each firm serves half the market ($R_A = ½$) in this equilibrium.

The equilibrium price in this model, $m_0^*(s)$, is illustrated in figure 2 and is the outcome of two offsetting factors. One factor is the price a firm would pay if it were a monopsonist operating with a market radius that is fixed at $R = ½$ due, e.g., to some geographic barrier. This price, labeled $m^m(s)$, is also illustrated in figure 2, and is an increasing function of s because the firm rationally absorbs part of the increased shipping costs represented by higher values of s.[10] The second factor is the effect of competition on price. Larger s diminishes competition between the firms, promoting a lower

[10] The reason a spatial monopsonist absorbs part of an increase in his/her suppliers' shipping costs is fundamentally the same as the reason why a monopolist passes only a portion of a cost increase forward to consumers. In either case, the firm accepts a lower profit *per unit* but maximizes total profits by selling (monopoly) or buying (monopsony) more than if none of the cost increase were absorbed.

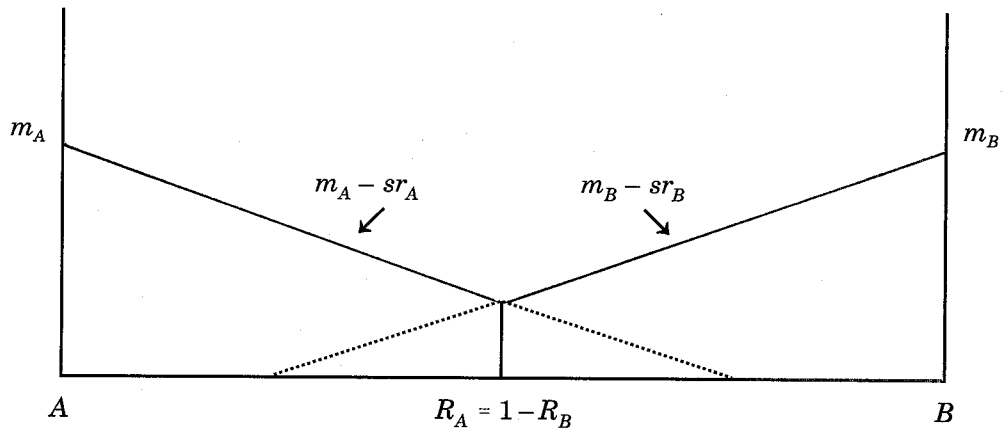

Figure 1. Duopsony FOB price competition without captive supplies

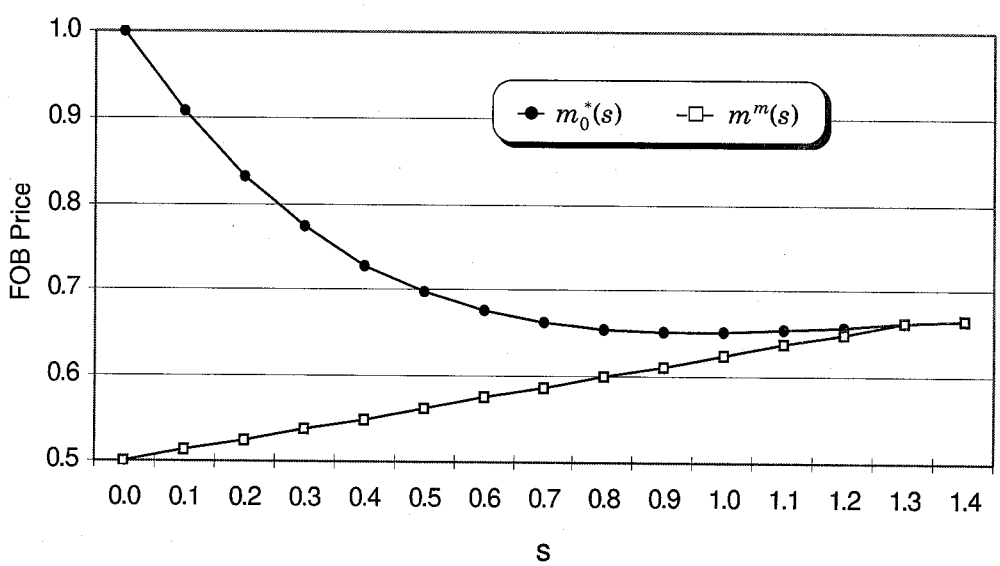

Figure 2. Optimal duopsony FOB prices

farm price. As figure 2 illustrates, this competition effect dominates over the interval $s \in [0, 0.9533)$, so that $m_0^*(s)$ is decreasing in s. Eventually, however, $m_0^*(s)$ reaches a minimum at $s \cong 0.9533$, and then begins to rise as the cost absorption effect dominates until $m_0^*(s) = 2/3$, the monopsony price, for all $s \geq 4/3$.

A Two-Stage Game Approach to Captive Supplies

We now introduce the possibility of packers offering captive supply contracts in this market. The objective is to derive market equilibria in the presence of captive supplies and compare them to the equilibrium without captive supplies derived in the prior section. 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.[11]

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 $[R_c, 0.5]$.[12] 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.[13] 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—namely, 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.[14] We solve the two-stage game by backward induction, beginning first with the solution to the stage 2 price-setting subgame.

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,

[11] This asymmetry in the use of captive supplies is consistent with actual practice in beef packing. Some processors procure the majority share of their supply through various forms of exclusive dealings, while other packers in the same geographic area make very little use of captive supplies (Ward et al.).

[12] The assumption that the right boundary of the captive supply region occurs at the market midpoint is made solely to simplify the exposition. Given the form of captive supply contract used in the model, the equilibrium location of the right boundary would be the market midpoint if it were determined endogenously.

[13] 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 influence the spot market price and, accordingly, we do not 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.

[14] The incentives to offer captive supply contracts that we demonstrate in this study for duopsony also apply to the monopsony case.

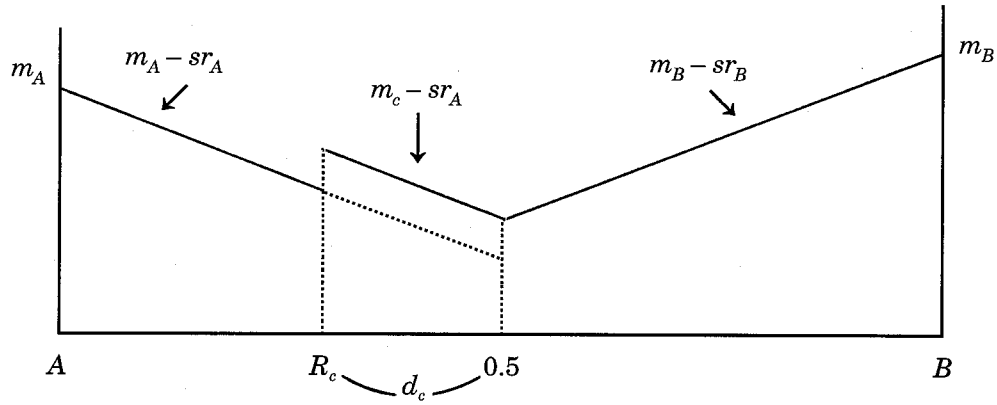

Figure 3. An asymmetric model of captive supplies

two possibilities are evident: (*a*) 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 (*b*) either firm can elect to "jump" across 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 across 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 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 optimum for each firm and then determine the values for s for which these prices are robust to potential boundary-jumping strategies. The firms' respective profit functions as monopsonists in their spot market areas are:

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

and

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

From the first-order conditions, we obtain optimal prices for firms A and B:

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

and

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

Thus in stage 2, $m_B^* \geq m_A^*$. 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 respective noncaptive supply regions are:

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

and

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

Solution to Stage 1

Firm A's total profit (Π_A^T) from both the noncaptive supply area and the captive supply area is specified as:

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

where m_A^* is firm A's optimal mill price from stage 2 as specified in (7), and $m_c = \max\{m_A^*, m_B^*\} = m_B^*$.[15] 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:

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

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

[15] 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 do not 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 $q^* = q(m_B^*)$.

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

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

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

Firm A therefore offers the captive supply contract $m_c = \max\{m_A^*, m_B^*\} = m_B^*$ to producers in the interval [1/6, 1/2]. 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 him/herself, worse off than if none signed the contract?

Rasmusen, Ramseyer, and Wiley (RRW) answer this question affirmatively in an analysis of exclusionary contracts designed to deter entry into 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. RRW demonstrate it is precisely this inability to coordinate that 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. Hence, 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/her contract cannot affect the ultimate success of the arrangement. Thus, as long as the producer is offered at least as much as could be received in the spot market in the equilibrium with captive supplies, the producer's equilibrium strategy is to ACCEPT the contract.[16] In essence, the knowledge that firm A has the economic incentive to implement a captive supply region enables A to secure captive supply contracts at a minimal cost.

Based on the above, the candidate subgame perfect equilibrium to this two-stage game involves firm A offering captive supply contracts in the region [1/6, 1/2], 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

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

task is to investigate the set of s values, if any, 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 set a price to enable it to procure product in the region [0, 1/6), and, given m_B^*, whether firm A wants to set price 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:

$$\max\{m_B\}\ \Pi_B^j = (1 - m_B)\int_0^{0.5}(m_B - sr)\,dr + (1 - m_B)\int_{5/6}^{1-R_A}(m_B - sr)\,dr, \tag{14}$$

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 (14) is:

$$m_B^j = \frac{32 + 6s + \sqrt{592 - 600s - 459s^2}}{72}, \tag{15}$$

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:

$$\Pi_B^0 = \max\left\{\Pi_B^*(s),\ \Pi_B^{j*}(s)\right\}, \tag{16}$$

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:

$$\max\{m_A\}\ \Pi_A^j = (1 - m_A)\int_0^{R_A}(m_A - sr)\,dr, \tag{17}$$

where

$$R_A = \frac{m_A - m_B^* + s}{2s} = \frac{m_A - 0.5 + 0.875s}{2s},$$

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 (17). The solution to the problem in (17) is:

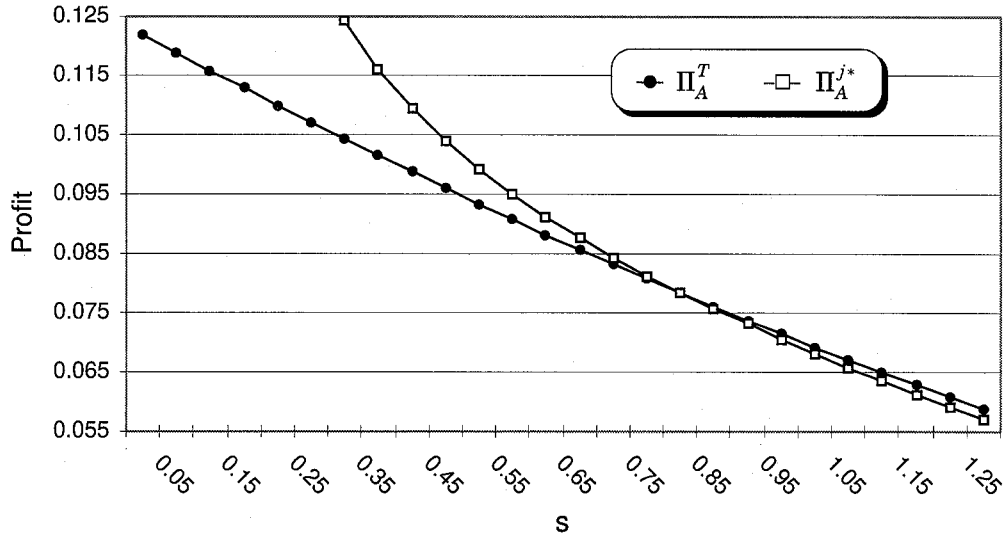

Figure 4. Firm A's profit under monopsony and boundary-jumping strategies

$$m_A^j(s) = \frac{32 - 14s + \sqrt{637s^2 - 392s + 592}}{72}, \tag{18}$$

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:

$$\Pi_A^0 = \max\left\{\Pi_A^T(d_c^*, s),\ \Pi_A^{j*}(s)\right\}, \tag{19}$$

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 reveals (as illustrated in figure 4) 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.

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 firms 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 ($s \geq 0.8665$ in our model), processors can use selective captive supply contracts to diminish the spot market price and increase profits at producers' expense.

For $s < 0.8665$, boundary jumping defeats an attempt to implement the monopsony solution given in (12) and (13). However, the boundary-jumping prices given in (15) and

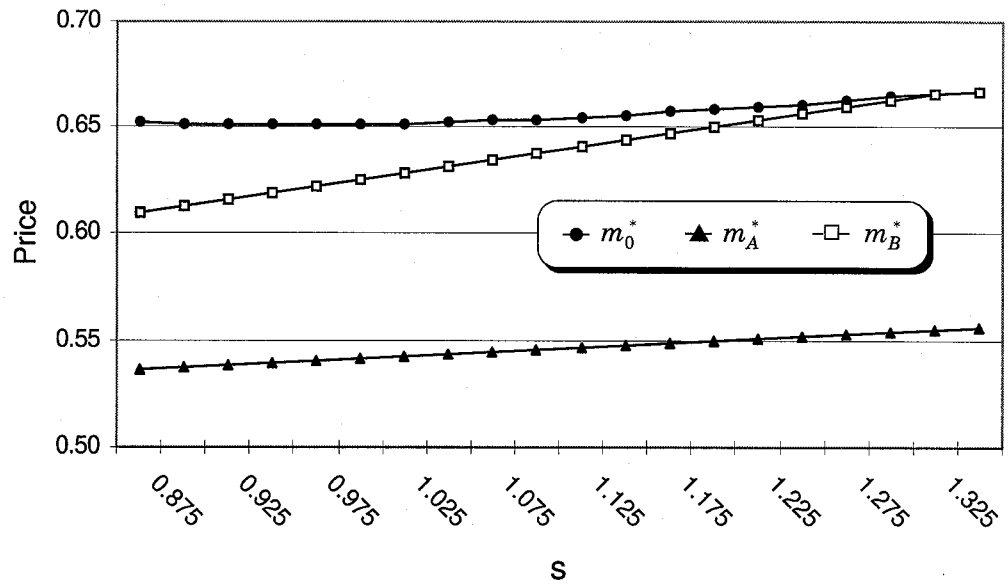

Figure 5. Optimal FOB prices with captive supplies

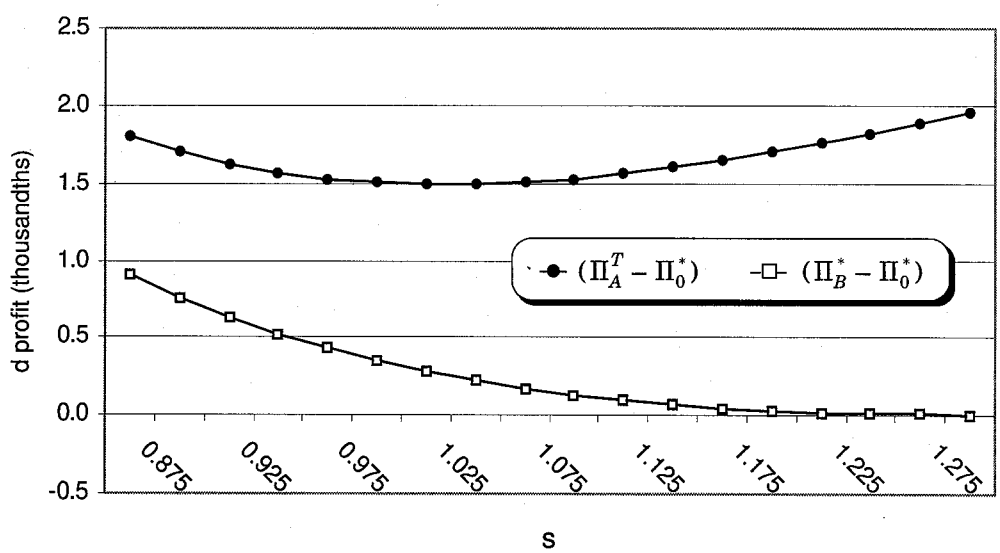

Figure 6. Differences between profits under captive supplies and duopsony

(18) do not themselves represent Nash equilibrium strategies. Rather, they respectively represent price strategies that 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 (19) for A and (16) 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 here.

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 setup.

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 respective firms' profit functions in the noncaptive supply areas are as follows:

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

and

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

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

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

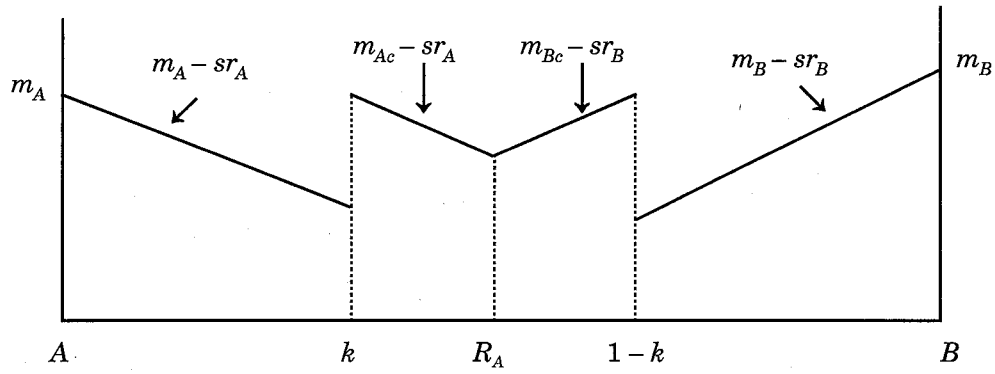

Figure 7. A symmetric model of captive supplies

Notice again that the larger the captive supply region (i.e., the smaller is k), the lower 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 respective firms' profits from offering captive supplies are as follows:

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

and

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

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:

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

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 restricted 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

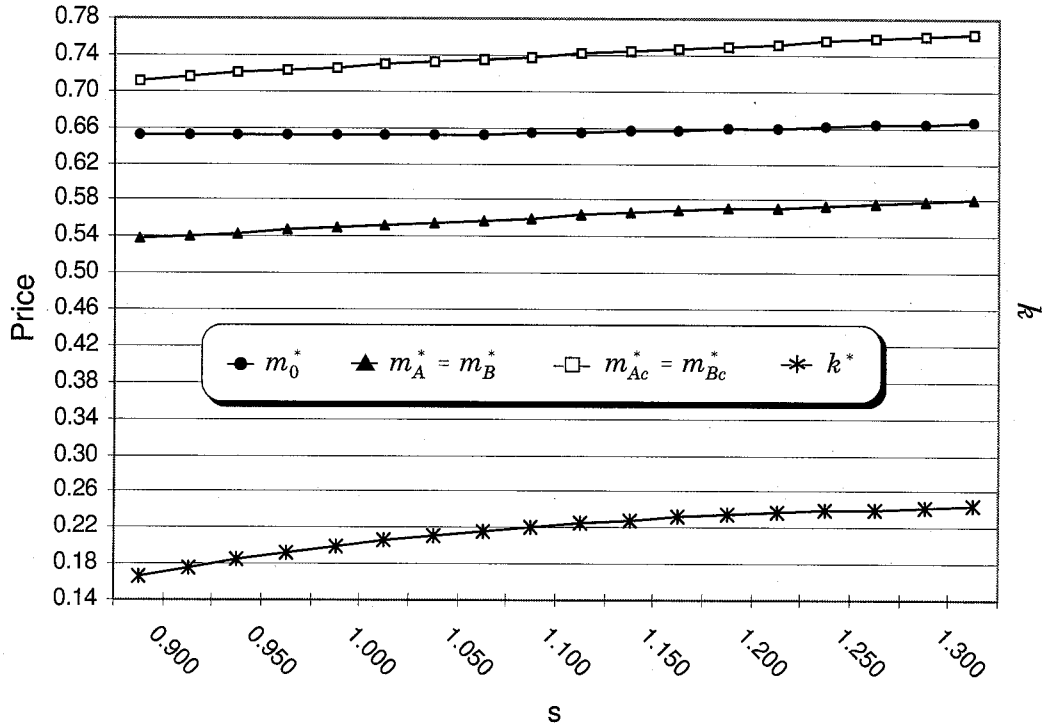

Figure 8. Optimal captive supply prices and boundary

duopsony price and the spot market contract price for all $k > 0$ (see figure 8). Hence, 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 ($1 - k_B$).[17] Each firm makes this decision to maximize its total profit from both the noncaptive 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:

$$\text{(26)} \qquad \max\{k\}\ \Pi_A^T = \Pi_A^* + \Pi_A^{cap}$$

$$= (1 - m_A^*)\int_0^k (m_A^* - sr)\,dr + (1 - m_{Ac}^*)\int_k^{R_A} (m_{Ac}^* - sr)\,dr$$

$$= \frac{k}{16}(2 - sk)^2 + \frac{(1 - m_{Ac}^*)}{8}(1 - 2k)(4m_{Ac}^* - s - 2sk),$$

[17] Because competition occurs only at the midpoint (R_A) of the captive supply region (see figure 7), this assumption seems reasonable.

where m_A^* and m_{Ac}^* are given in (22) and (25), respectively. 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/she would prefer to offer higher prices to more distant producers to compensate partially for their higher shipping costs. For large values of s, the duopsony price in (4) is *less* than the price that would maximize profits considering only the producers in the captive supply region $[k, 0.5]$. Thus, the higher contract price and the higher production it induces can actually increase profits from serving those producers relative to what is earned under pure duopsony.

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. However, the boundary-jumping strategies themselves cannot constitute Nash equilibria, because 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^*, $m_A^* = m_B^*$, and $m_{Ac}^* = m_{Bc}^*$ for k, m_A, m_B, m_{Ac}, and m_{Bc}) 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 $k^*(s)$, $m_{Bc}^* = m_{Ac}^*$, and m_B^*. Firm A's profit-maximization problem under a boundary-jumping strategy is:

$$\max\{m_A\}\, \Pi_A^j = \Pi_A^{cap} + (1 - m_A)\left[\int_0^k (m_A - sr)\,dr + \int_{1-k}^{R_A} (m_A - sr)\,dr\right], \tag{27}$$

where

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

The solution to (27) is:

$$m_A^j(s \mid k^*) = \frac{2(12s + 8 - 31sk^*) + \sqrt{144s^2 - 240s - 1{,}896s^2k^* + 148 + 284sk^* + 3{,}853s^2k^{*2}}}{36},$$

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

We express A's overall profit as:

$$\Pi_A^0 = \max\left\{\Pi_A^T(s \mid k^*),\ \Pi_A^{j*}(s \mid k^*)\right\}.$$

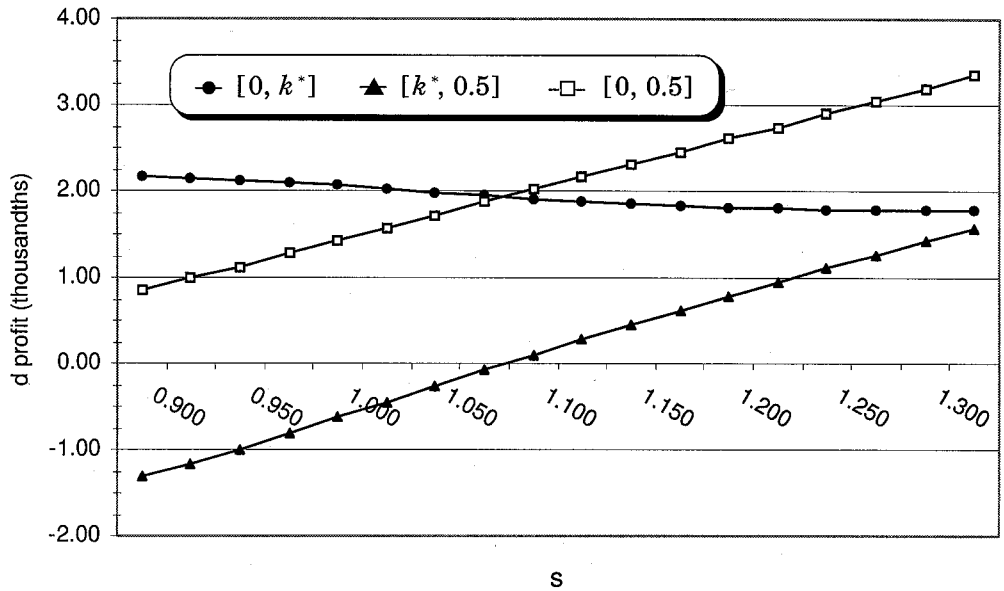

Figure 9. Differences in processor profits under captive supplies and pure duopsony

Comparison of Π_A^T and Π_A^{j*} indicates that firm A will set a spot price that enables it to jump to B's market area, given k^* and $m_B^* = ½ + sk^*/4$, when $s < 0.893$. Therefore, the solutions for $m_A^* = m_B^*$, $m_{Ac}^* = m_{Bc}^*$ from (22) and (25), and k^*, as illustrated in figure 8, apply only for $s \geq 0.893$. Again, when space is less important in the sense of small s, 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.

Implications for Empirical Analysis

Several implications from the models developed in this study are testable, given the appropriate data sets. If captive supply contracts are being used to influence the cash price, the model predicts that, ceteris paribus, those feedlots with captive supply contracts will be located at greater distances from the packer than their cash market suppliers (i.e., the captive supply area provides a boundary around the cash market

area). The model also predicts that the producer price in the captive supply contracts must be at least as high as the cash market price, holding other factors such as quality constant. Further, the model posits that captive supply contracts will be more prevalent in the more concentrated procurement areas because they are rendered ineffective by boundary jumping in markets when competition (as measured by s in our model) is sufficiently intense.

In principle, an encompassing empirical analysis could treat a packing plant's share of throughput from captive supply contracts as a limited dependent variable, and express it as a function of several explanatory variables chosen to test the importance of the factors discussed here versus other possibilities discussed by Love and Burton; Ward, Koontz, and Schroeder; and others. Key explanatory variables suggested by this analysis include measures of the competition faced by the plant, including number of direct competitors and distance separating competitors.

Due to concerns about rising concentration and vertical control in the livestock sector, USDA's Grain Inspection, Packers and Stockyards Administration (GIPSA) has used its authority under the Packers and Stockyards Act to generate detailed data sets on packer-feeder transactions. The most comprehensive of the GIPSA data sets involved collecting transaction records for 43 packing plants over a period of roughly one year, from April 1992 to April 1993.[18] This and similar GIPSA transactions-level data sets might be used to test implications of the models presented here.

Concluding Comments

Our spatial models show that processors may be able to use captive supply contracts to influence 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. This conclusion is important because prior studies of this phenomenon have tended to emphasize 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 obtaining assured supplies, reducing the distortions due to processor monopsony power (Love and Burton), and addressing problems of adverse selection or moral hazard among producers.[19] Nonetheless, even if captive supply contracts are implemented for some other reason, this analysis has shown that their presence may influence the cash market price to producers' detriment.

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,

[18] Ward et al., and Ward, Koontz, and Schroeder have discussed and analyzed this data set.

[19] See Katz for a general discussion of these issues, and Antonovitz, Buhr, and Liu for applications to meat packing.

captive supply regions form an effective spatial barrier between firms, enabling each to act as a monopsonist in the spot market area near its respective location and earn more profits than would be attainable from transacting solely in the spot market.

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