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A Strategic Rationale for Captive Supplies

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Partial backward integration is prevalent in many agricultural and natural resource processing industries. A strategic rationale for partial backward integration is developed for a dominant firm with a competitive fringe purchasing from competitive input suppliers. A partially backward integrated dominant firm potentially can increase profit through production efficiency gains and through a lower price for externally purchased input. The optimal degree of backward integration results when the dominant firm's profit from exerting monopsony market power in the external spot market equals its profit from producing raw input internally, less the incremental cost of acquiring internal raw input production capacity. Comparative statics results are consistent with recent empirical studies of the beef packing industry.

Key words: backward integration, captive supplies, dominant firm, fringe firms, meat packing, monopsony, price discrimination, vertical integration

Introduction

Academic and legal debate over the costs and benefits of vertical integration is both well known and lengthy. On one side, economists see firms' decisions to vertically integrate as a means of reducing transactions costs, assuring supply, reducing price risk, or of alleviating efficiency losses resulting from resource underutilization (McGee and Bassett; Williamson 1975, 1985, 1989; Wu; Azzam 1996). On the other side, economists see vertical integration as a means for firms to reduce competition or extract market rents (Scherer; Perry 1978a, 1989). To date, most discussion has focused on the effects of a monopolist integrating forward into a competitive downstream intermediate product market. Little work exists on the reverse case of a monopsonist integrating backward into a competitive input market (Perry 1978b; McGee and Bassett; Hart and Tirole). However, backward integration is of growing importance in many agricultural and natural resource industries, including poultry processing (Knoeber and Thurman), meat packing (Azzam 1996; Kliebenstein and Lawrence), and forest product industries (Murray).

Backward integration occurs through acquiring input suppliers, establishing long-term contracts with existing suppliers, or investing in new input production capacity through internal corporate growth. In some industries, there is increasing concern about

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the effects of such integration on remaining unintegrated input suppliers. Recently, cattle producers—through the Western Organization of Resource Councils, a federation of citizen groups composed of farmers, ranchers, and small businessmen—petitioned the Secretary of Agriculture to restrict packers' procurement practices. Specifically, they argued:

> Packers' direct ownership and feeding of cattle for slaughter and their procurement of slaughter supplies through forward contracts have decreased prices paid to cattle producers. In addition, because forward contracts are not traded publicly and packer fed cattle are not sold publicly, these practices unjustly discriminate against some producers and provide unreasonable preferences to others (*Federal Register*, 14 January 1997, p. 1846).

While several recent studies have found support for the proposition that packer concentration may be allowing firms to exert limited market power in the fed cattle markets (e.g., Azzam 1992; Azzam and Pagoulatos; Koontz and Garcia; Schroeter; Schroeter and Azzam; Schroeder et al.), other studies do not reject competitive behavior (e.g., Muth and Wohlgenant; Stiegert, Azzam, and Brorsen). Packer concentration, in itself, does not imply that fed cattle prices are always lower as a result of increasing concentration (Azzam and Schroeter). After an extensive review of this literature, Azzam and Anderson found that, while market power is limited, "the evidential balance from time series studies using national data appears to weigh in favor of the hypothesis that meat packer conduct in live cattle markets is not competitive" (p. 110). Sexton and Lavoie similarly found that, with a few exceptions, studies generally tend to show "some statistical evidence of market power, although the measured departures from competition have mostly been small" (p. 50).

The effects of increasing packer concentration in the red meat packing industry were recently investigated through a congressionally mandated U.S. Department of Agriculture (USDA) Packers and Stockyards Administration (PSA) study. The PSA study reports that, during the April 5, 1992 to April 3, 1993 interval, the 43 largest steer and heifer slaughter plants procured 82% of fed cattle through the spot market, 8% through marketing agreements where a packer agrees to purchase a specific number of cattle per time period, 7% through forward contracts, and 3% through custom feedlot arrangements or through wholly owned feedlot operations (p. 170). The study also found large firms are more likely to use marketing agreements and forward contracts to purchase cattle than are other firms. For example, Williams et al. report, "ConAgra, Excel, and IBP account for 73 percent of spot market transactions, but 88 percent of marketing agreements and 95 percent of forward contract transactions" (p. 16).

In the cattle industry, captive supplies include cattle that are packer-owned or fed and cattle procured through forward contracts or long-term marketing agreements (Ward). This definition is aligned with industrial organization tradition that defines an upstream or downstream firm as vertically integrated if it controls either directly or indirectly the decisions made within the vertical structure (Tirole, p. 170). Hence, in 1992–93, about 18% of fed cattle purchased by packers were procured through captive supply arrangements, with three large firms accounting for the vast majority of these transactions. There is also evidence in the beef packing industry that the quantity of fed cattle purchased through captive supply arrangements has remained nearly constant during the last decade (USDA, table 16).

Many natural resource markets exhibit characteristics similar to the beef packing industry. Typically, processing mills are spatially distributed with high transportation costs associated with moving raw products to mills, limiting competition among natural resource buyers. In the forest industry, large processing firms own or lease vast tracts of timberland, but also purchase timber from outside suppliers. In 1991, U.S. forest product firms internally supplied 33% of total volume harvested and about 38% of softwood harvested (Powell et al.). In 1994, 31 forest products firms in the U.S. and Canada owned 45 million acres of industrial timberlands and controlled another 162 million acres through lease arrangements with nonindustrial landowners who own no processing facilities (Mies et al.). These holdings represent roughly 34% of total U.S. and Canadian commercial-grade timberlands. The remaining two-thirds of productive timberlands are owned and controlled either by nonindustrial landowners or by governments. Farmers, the largest identifiable group of nonindustrial landowners, own 90% of nonindustrial land in tracts of less than 100 acres.

Clearly, firms use various mechanisms to achieve backward integration into input markets. There is ample evidence, at least in the beef packing industry, that large firms, more than small firms, use these mechanisms to achieve at least partial backward integration. In this investigation, we develop an economic rationale for this behavior. While in reality firms may use vertical integration for a number of reasons, we follow Perry (1978a) and focus on firms' strategic use of vertical integration to achieve higher profits. We demonstrate both graphically and analytically some important implications of backward integration that may be achieved through controlling a portion of the raw-input production sector either through long-term contracts or acquisition of upstream firms. Contrary to the competitive notion that vertical integration is a purely "internal affair" that does not affect third parties, we find that backward-integrated processors can potentially benefit from at least two sources of increased profitability. First, a backward-integrated dominant firm benefits from production efficiency gains (e.g., Azzam 1996). Second, a backward-integrated dominant firm may benefit from a lower acquisition price for externally supplied raw inputs. We also show a number of important comparative statics results relating to backward integration and how they reflect findings of the recent PSA study.

The analysis that follows extends Perry's (1978b) work on backward integration in several directions. First, our model extends Perry's analysis from the monopsony case to a backward-integrated dominant firm with a competitive fringe of input purchasers. Second, we add structure consistent with agricultural and natural resource processing industries to the assumed technology that results in a more detailed and clearer exposition of the potential market effects of backward integration. These assumptions also allow us to closely connect the theoretical model to an intuitive graphical presentation. Third, our analysis includes comparative statics results for changes in plant capacity, an important factor in natural resource markets. Fourth, we consider both short- and long-run effects of backward integration in our analysis, where the short run is defined by fixed plant capacity and a given level of backward integration. In contrast, Perry (1978b) considers only the long-run equilibrium case.

The Model: A Graphical Approach

We consider a market with a large number of spatially distributed competitive input suppliers and a downstream spatially concentrated processing industry—a situation likely to result in a monopsonized market solution where the local industry gets a spatial monopsony due to transportation costs. This market structure might occur in industries where firms possess scale economies over some range of operations and where transportation costs associated with assembling the raw input are high. Under these conditions, processors have an incentive to be spatially distributed so that each processing firm dominates its local input market area (Greenhut, Mai, and Norman; Lofgren). We assume distant processing firms or mills in various directions from the dominant mill are fairly numerous, so that each consumes only a small portion of the locally supplied input. Bresnahan and Reiss have shown competitive conditions are typically achieved once a market has between three and five competitors, suggesting that the dominant mill may reasonably assume the distant mills constitute a "competitive" fringe of input consumers. To simplify our analysis, we consider a single dominant processing firm surrounded by a competitive fringe of processors.

In developing this model, we make a number of other simplifying assumptions. First, we assume that the number of firms is fixed and processors' output and their raw input are homogeneous. Second, we assume that processors are competitive in their output markets. This is reasonable when numerous firms produce a homogeneous output. Third, we assume that processing firms produce a single output employing a quasi-fixed proportions technology that allows no substitution between the raw input and a vector of other production inputs. This assumption allows us to focus the analysis on the interaction of upstream and downstream firms in an input market. Fourth, we assume the dominant firm enjoys falling average production costs as output expands toward optimal capacity utilization, and that as output rises above the optimum, average cost rises. This assumption is consistent with a short- or intermediate-run model of an industry where capital costs are high and plant capacity is fixed.

The market situation described above is depicted in figure 1. On the left, total upstream input supply is defined as $x_s = x_s(w_m)$, where w_m is market price. Acting as price takers, fringe processing firms set their optimal input levels so that aggregate fringe input demand is $x_d = x_d(w_m)$. The residual supply facing the dominant processor is shown on the right as $x_{rs}^0 = x_{rs}^0(w_m) = x_s(w_m) - x_d(w_m)$. In the absence of vertical control, the dominant firm acts as a monopsonist with respect to residual supply, maximizing profit by setting value marginal product for raw input x, VMP_x, equal to marginal outlay for that input, MO_{rs}^0. In figure 1, this occurs at quantity x_m^m and price w_m^m.

From a technical efficiency point of view, the dominant firm underemploys the raw input at the monopsony solution defined in figure 1. Assuming a constant raw input price, the firm could reduce average cost per unit of output by expanding production. Assuming output price is fixed, this would raise profit. However, unless the firm is able to price discriminate among input suppliers, this alternative is not profitable. Without price discrimination, the dominant firm must pay input suppliers a higher price for all units purchased to expand output, wiping out cost savings from increased production. However, by partially backward integrating into its input market, the dominant firm can simultaneously increase profit by expanding input use through internally produced input supply to partially eliminate the efficiency loss from input underemployment and

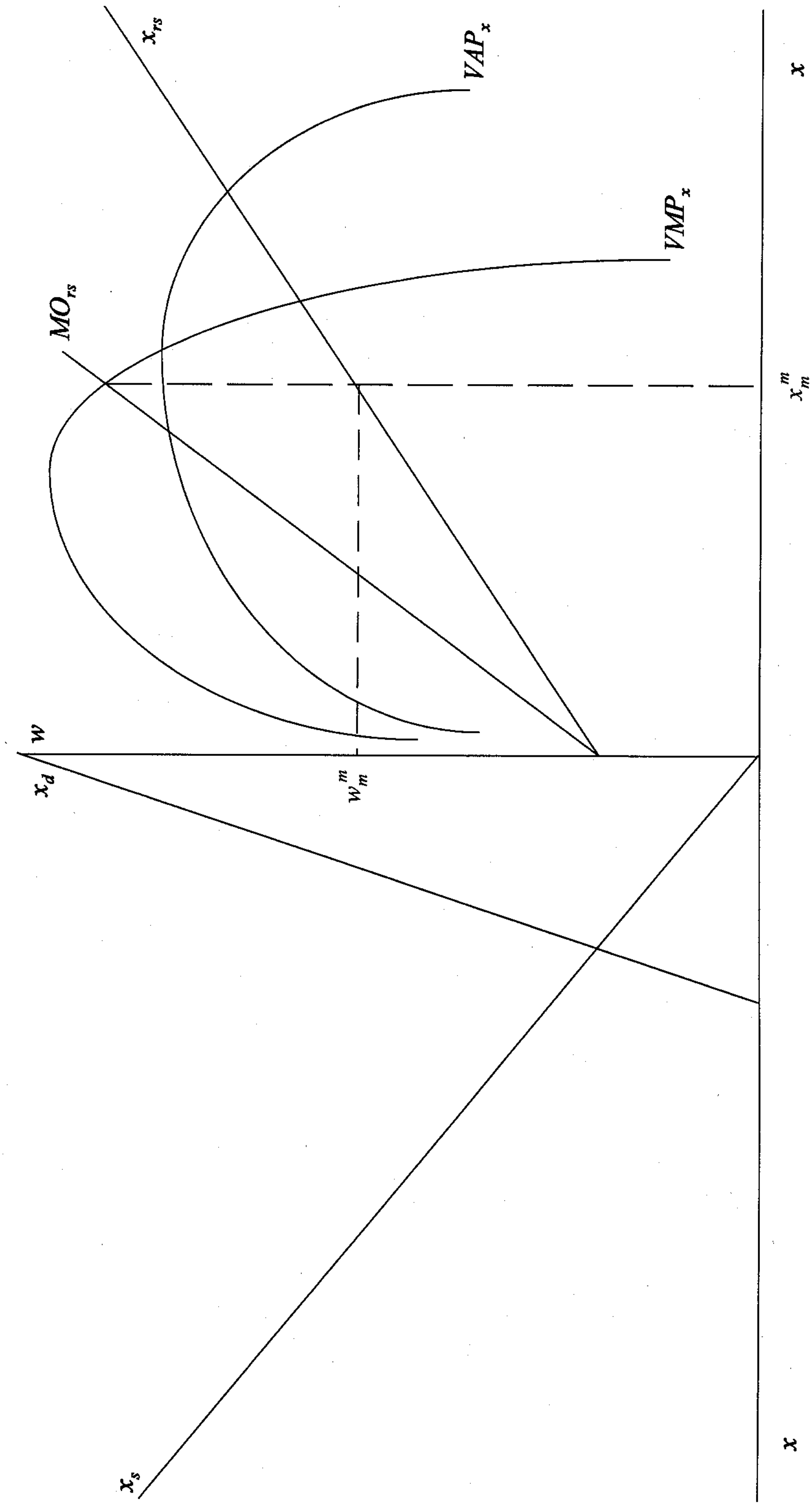

Figure 1. Economics of monopsony

by continuing to exercise monopsony market power in purchases from unintegrated input suppliers.

Following Perry (1978b), we define the degree of backward integration as the fraction of identical raw input suppliers controlled by the dominant processor. The dominant firm can achieve backward integration either through acquiring a fraction of the upstream firms in the raw input industry or by entering into exclusive long-term contracts with input suppliers who control a portion of total supply. For the moment, assume that integration is achieved through acquisition. Suppose the dominant firm purchases fraction α of raw input suppliers so that internally it produces amount x_c of the raw input. It then purchases quantity x_m from the spot market. In this case, the dominant firm is able to segment its input market, internally supplying raw input at one transfer price and externally purchasing raw input in the spot market at another price. On the right-hand side of figure 2, the dominant firm's internal supply (marginal cost) of raw input is given as $x_c = \alpha x_s(w_c)$, where w_c is the internal transfer price the dominant firm "pays" its internal input supply subsidiary, and its residual spot market supply is given as $x_{rs} = x_{rs}(w_m) = (1 - \alpha)x_s(w_m) - x_d(w_m)$.

To maximize profit, the dominant firm will continue to act as a monopsonist with respect to its external residual input supply, but now will operate its internal raw input-producing facilities at the quantity that equates VMP_x to the marginal factor cost of the raw input (*MFC*) (Perry 1978b), where $MFC = w_c = x_s^{-1}(x_c/\alpha)$, and $x_s^{-1}(\cdot)$ is the inverse supply function obtained by solving the firm's internal supply, $x_c = \alpha x_s(w_c)$, for w_c. With partial integration in the input market, the dominant firm sets total raw input use to equate its marginal outlay for externally purchased input plus marginal factor cost for internally controlled input ($MO_{rs} + x_c$ in figure 2) equal to VMP_x. To achieve this result, the dominant firm chooses the amount of input produced internally, x_c, and the price it pays in the spot market, w_m. Total input quantity for the dominant firm is $x_t = x_c + x_{rs}(w_m)$. In figure 2, optimal total input use with backward integration is x_t^c, with quantity x_m^c purchased in the spot market and quantity x_c^c produced internally. Equilibrium spot market price is now given by w_m^c, and the internally supplied raw input transfer price is w_c^c. As a result of backward integration, total input use has expanded from x_m^m to x_t^c, and the equilibrium spot market input price has fallen from w_m^m to w_m^c.

The dominant firm reaps two potential benefits from partial backward integration into its input market. First, it benefits from efficiency gains of expanded production. In figure 2, this gain is measured as area *abcd* under the dominant firm's input demand function for x. Second, the dominant firm benefits (in this particular example) from paying a lower spot market price for externally supplied raw input. This gain is given by area *efgh* in figure 2. That is, partial backward integration results in a reduction in the price for external raw input purchases amounting to $w_m^m - w_m^c$. This benefit is case specific and depends, among other things, on the slope of the dominant firm's input demand for x (the slope of VMP_x). If, for example, the dominant firm's input demand was flatter near the equilibrium input quantity x_t^c, then the equilibrium dominant firm monopsony price w_m^m would be less than the equilibrium external input price w_m^c. In this case, the dominant firm would suffer a loss from having to pay a higher price for externally supplied input after backward integration.

To obtain these benefits, the dominant firm must bear additional costs. The integrated firm produces x_c^c of raw input internally. Total variable cost of this production

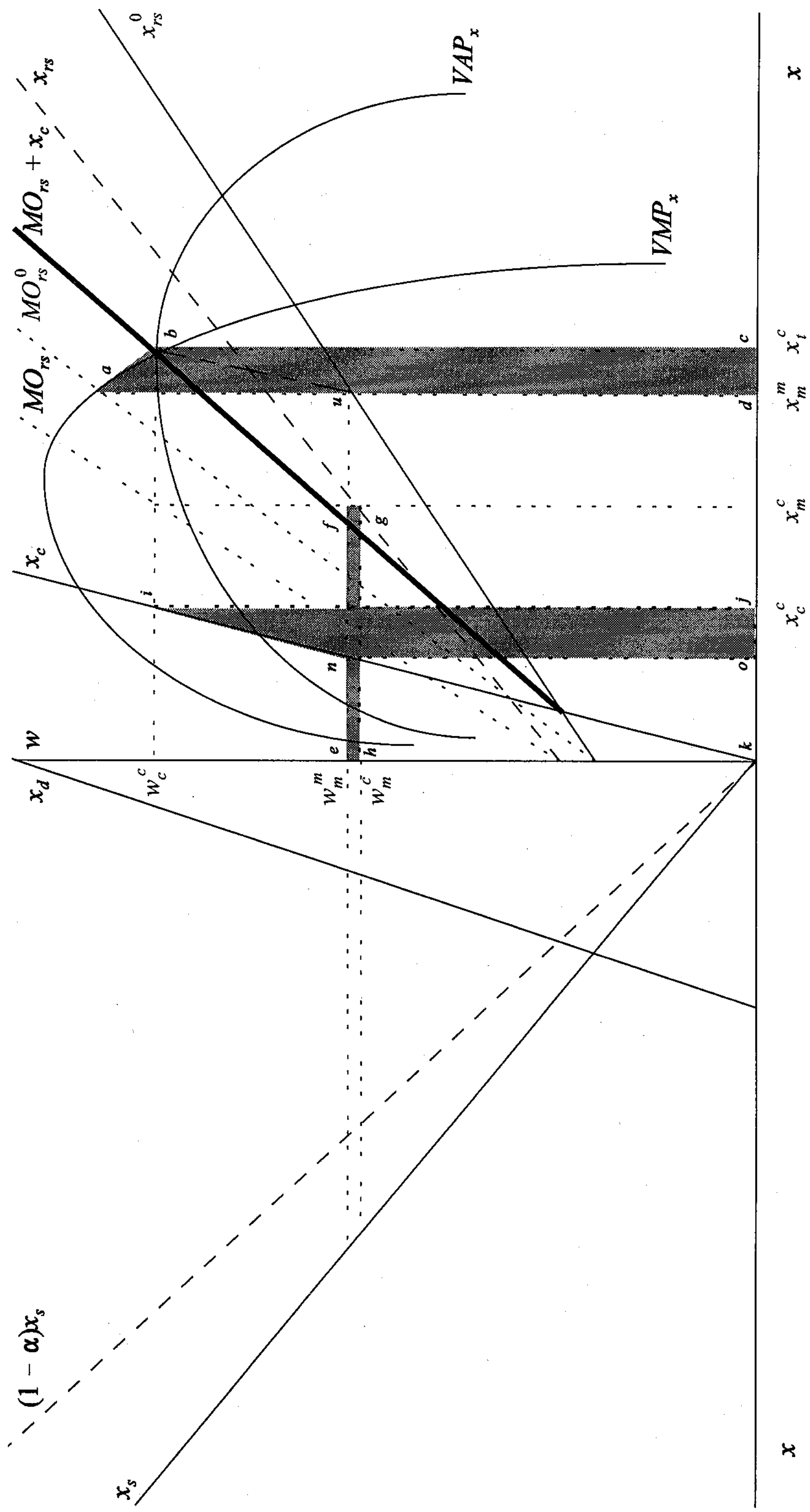

Figure 2. Economics of vertical integration

is area *ijk* in figure 2. However, the costs to the dominant firm of acquiring this upstream production capacity are not covered. Acquisition costs are related to rents accruing to input suppliers before they are purchased. There are many possibilities (such as greenfield investment, joint venture, buyout, long-term contract), all of which vary as to risk, capital commitment, and level of control.

For simplicity, we follow Perry's (1978b) case 1, and assume that processors can acquire any fraction of upstream firms by paying them the present value of the stream of per period initial rents, so that acquired suppliers are indifferent between maintaining independent ownership or being acquired by the dominant processing firm. In figure 2, this amounts to paying the acquired suppliers the equivalent of area *enk* at each time period. Hence, per period total cost of internal production is given by area *enijk*. This is the same payment that would be required for input purchases made through establishing exclusive supply contracts when the dominant firm has perfect information about upstream firms' production costs and when the dominant firm does not in any way act as a "predator" in forming long-term contracts. Before acquisition, the dominant firm incurred external input costs of area *enok* for input production that becomes internalized in the vertically integrated firm. Thus, the net increase in input costs after integration is area *nijo*. On balance, the total benefit from backward integration is area *abcd* plus area *efgh* minus area *nijo*.

While we assume that the number of fringe firms is fixed, it is possible to draw some conclusions about the effects of price changes resulting from vertical integration on the profitability and behavior of fringe processors. In the case where backward integration results in an equilibrium external input price that is lower than the pre-integration input price, fringe processing firms' profitability rises, creating an incentive for the fringe to expand operations. Fringe firm expansion will place competitive pressure on the dominant firm, and may ultimately result in lost market share for the dominant firm. Alternatively, when backward integration results in a higher equilibrium external input price, this creates an unfavorable economic environment for fringe processors. In this case, backward integration could be used as a means of raising rivals' costs to allow the dominant firm to capture a larger market share (Salop and Scheffman).

Mathematical Model

The remainder of this article provides a brief formal analysis of captive supplies. As discussed above, we assume that the dominant firm produces a single output, y, employing a quasi-fixed production technology that does not allow substitution between input x and other inputs $\mathbf{z}$ and capacity k, but does allow substitution among inputs other than x. Further, we assume that the dominant firm's plant size k is fixed in the short run, so that cost is conditional on plant size.

This technology is given by:

$$(1) \qquad y = \min\big(x/\beta,\ f(\mathbf{z}, k)\big),$$

where β represents a constant x-to-y conversion ratio, k is capacity or quantity of capital, $\mathbf{z}$ is a vector of input quantities other than x and k, and $f(\mathbf{z}, k)$ is concave with positive and declining marginal products for capital k and all remaining inputs $\mathbf{z}$ (Sexton). Cost minimization requires $y = x/\beta = f(\mathbf{z}, k)$. The cost function for this technology is written as:

(2) $$C(y, w, \mathbf{v}; k) = y\beta w + c(y, \mathbf{v}; k) + FC,$$

where w is the price of raw input x, $\mathbf{v}$ is a vector of variable input prices associated with $\mathbf{z}$, and FC is fixed costs. The first term represents raw input costs, and $c(y, \mathbf{v}; \text{k}) = \min_{\mathbf{z}} \{\mathbf{v}'\mathbf{z}: f(\mathbf{z}, k) \geq y\}$ represents costs of all remaining inputs other than capital (FC). Given these assumptions, costs can be reformulated in terms of raw input quantity so that

(3) $$C(y, w, \mathbf{v}; k) = xw + c(x/\beta, \mathbf{v}; k) + FC.$$

For now, we set aside the long-run problem of determining the optimal degree of backward integration. Here, we concentrate on the short-run problem of determining the optimal quantity of raw input to produce internally and the optimal price to set in the unintegrated upstream spot market, given that the dominant firm integrates with proportion α of the upstream industry. To maximize short-run vertically integrated profit, the dominant firm must maximize the joint profit of its processing and raw input-producing operations. This is achieved by acting as a monopsonist with respect to its upstream spot market residual supply and operating its internal input supply unit according to the competitive rule of choosing internal input production so that marginal benefit equals marginal cost. Total variable cost of internal input production is given by:

(4) $$TVC_x^c = \int_0^{x_c} x_s^{-1}(x/\alpha)\, dx,$$

where $x_s^{-1}(x/\alpha)$ is the inverse supply function for the fraction of input supply produced internally, and x_c is the quantity produced internally. Fixed cost for these inputs is also a function of α, $fc(\alpha)$, since processors must either purchase or negotiate long-term contracts with existing input suppliers. The dominant firm's output, expressed in terms of input x, is $y = [(1 - \alpha)x_s(w_m) - x_d(w_m) + x_c]/\beta = [x_{rs}(w_m) + x_c]/\beta$.

Given these definitions, the dominant firm's short-run profit-maximization problem is specified as:

(5) $$\begin{aligned} \max_{w_m, x_c} \pi = {} & p\left[x_{rs}(w_m) + x_c\right]/\beta - w_m\left[x_{rs}(w_m)\right] \\ & - \left[\int_0^{x_c} x_s^{-1}(x/\alpha)\, dx + fc(\alpha)\right] \\ & - c\left(\left[x_{rs}(w_m) + x_c\right]/\beta, \mathbf{v}; k\right) - FC. \end{aligned}$$

The first term is revenue from output sales, the second term is externally supplied input cost, the third term is internally supplied input cost, the fourth term is other input costs conditional on k, and the fifth term is fixed costs. The dominant firm's short-run profit-maximizing first-order conditions are:

(6) $$\frac{\partial \pi}{\partial w_m} = \left[\frac{p - c'(\cdot)}{\beta} - w_m\right]\left[\frac{\partial x_{rs}}{\partial w_m}\right] - x_{rs}(w_m) = 0$$

and

(7) $$\frac{\partial \pi}{\partial x_c} = \frac{p - c'(\cdot)}{\beta} - x_s^{-1}(x_c/\alpha) = 0,$$

where $c'(\cdot)$ is the derivative of $c(\cdot)$ with respect to total raw input quantity x. Interpreting equation (7), the dominant firm sets internal raw input production to equate $VMP_x = (p - c'(\cdot))/\beta$ with its internal marginal cost of input production. If vertical integration is achieved only through long-term contracting, equation (7) gives the dominant firm's optimal contract quantity, given that it has already contracted with portion α of upstream firms.

Equation (6) can be expressed in elasticity form as:

(8) $$\frac{\partial \pi}{\partial w_m} = \frac{p - c'(\cdot)}{\beta} - w_m\left[1 + \frac{1}{\varepsilon_{rs}}\right] = 0.$$

Interpreting equation (8), the dominant firm sets raw input price to equate VMP_x with its marginal outlay for externally purchased input $MO_{rs} = w_m(1 + (1/\varepsilon_{rs}))$, where ε_{rs} is the price elasticity of residual supply and

$$\varepsilon_{rs} = \left(\frac{(1 - \alpha)\varepsilon_s x_s - \varepsilon_d x_d}{(1 - \alpha)x_s - x_d}\right).$$

Contracting must make input suppliers at least as well off as they would be if they had not contracted. Hence, the minimum contract price is

(9) $$w_c^* = \left[w_m^* \alpha x_s(w_m^*) + \int_{\alpha x_s(w_m^*)}^{x_c^*} x_s^{-1}(x/\alpha)\, dx\right] \Big/ x_c^*,$$

where x_c^* is the optimal contract quantity, and w_m^* is the initial equilibrium price in the external input market. It is apparent from equation (9) that when vertical control is established through long-term contracts, the equilibrium contract price must be at least as high as the external spot market price.

It is instructive to contrast the dominant firm-competitive fringe solutions with and without backward integration. Because a processor executing long-term contracts does not act as a monopsonist with respect to its contractors, contracting for inputs expands the dominant processor's use of input x. This can be shown by comparing total input use under the two equilibria. Total input use with contracting is $x_t^c = x_{rs}(w_m) + \alpha x_s(w_c) = (1 - \alpha)x_s(w_m) - x_d(w_m) + \alpha x_s(w_c)$, and total input use without contracting is $x_t^m = x_s(w_m) - x_d(w_m)$. Subtracting x_t^m from x_t^c gives $\alpha[x_s(w_c) - x_s(w_m)] > 0$. Assuming positive contract quantity, equation (9) implies that contract price w_c exceeds spot market price w_m. Upward-sloping supply then implies that $x_t^c > x_t^m$, a result consistent with Perry (1978b).

A comparison of the external spot market price with and without contracting begins by solving equation (8) for w_m^c:

$$(10) \qquad w_m^c = \frac{VMP_x^c}{1 + 1/\varepsilon_{rs}^c},$$

where VMP_x^c is value marginal product evaluated at x_t^{c*}, and ε_{rs}^c is the residual supply curve elasticity with contracting. With no contracting, this relationship is specified as:

$$(11) \qquad w_m^m = \frac{VMP_x^m}{1 + 1/\varepsilon_{rs}^m}.$$

Combining equations (10) and (11), the external spot market price under partial contracting can be compared with the spot market price in the case of no contracting:

$$(12) \qquad \frac{w_m^c}{w_m^m} = \frac{VMP_x^c}{VMP_x^m}\left(\frac{1 + 1/\varepsilon_{rs}^m}{1 + 1/\varepsilon_{rs}^c}\right).$$

Larger input use implies $VMP_x^c < VMP_x^m$ because input demand is downward sloping. Therefore, the ratio of marginal value products in equation (12) is less than one. If $\varepsilon_{rs}^m = \varepsilon_{rs}^c$, then w_m^c/w_m^m will be less than one. However, there is no reason to believe that ε_{rs}^m will equal ε_{rs}^c, because ε_{rs}^c depends on the degree of backward integration and both ε_{rs}^c and ε_{rs}^m depend on equilibrium spot market supply and demand quantities. While contracting expands the dominant firm's use of input x, it is not clear exactly how the elasticities of residual demand are affected. However, if x_s, x_d, and the elasticities of total supply and fringe demand are assumed constant, then increased contracting results in lower values of $1 + (1/\varepsilon_{rs}^c)$. Under this rigid assumption, the price ratio w_m^c/w_m^m rises with increased backward integration. Without this assumption, the integrated spot market price will be less than, equal to, or greater than the unintegrated spot market price when the ratio VMP_x^m/VMP_x^c is greater than, equal to, or less than the ratio $\{(1 + 1/\varepsilon_{rs}^m)/(1 + 1/\varepsilon_{rs}^c)\}$.

Comparative Statics Results

To better understand how changes in the dominant firm's capacity (k) and proportion of input suppliers with which the dominant firm contracts (α) affect the equilibrium contract quantity and spot market price, we perform comparative statics by totally differentiating equations (6) and (7). In this short-run analysis, both capacity and the degree of backward integration are taken as given.

One unambiguous result can be obtained from the comparative statics analysis. An increase in the dominant firm's output production capacity results in a rise in the equilibrium external spot market input price,

(13)
$$\frac{dw_m}{dk} = \frac{-1}{|\mathbf{H}|}\frac{\partial x_s^{-1}(\cdot)}{\partial x_c/\alpha}\frac{1}{\alpha}\frac{\partial^2 c(\cdot)}{\partial y \partial k}\frac{\partial x_{rs}(w_m)}{\partial w_m}\frac{1}{\beta} > 0,$$

where $|\mathbf{H}|$ is the determinant of the Hessian matrix $\mathbf{H}$. Since $\mathbf{H}$ is a 2×2 matrix and must be negative semidefinite for profits to be maximized, $|\mathbf{H}|$ must be positive. The first right-hand-side (RHS) term in expression (13) is negative. The second RHS term is positive since input supply is upward sloping. The third RHS term is positive. The fourth term, $\partial^2 c(\cdot)/\partial y \partial k$, is negative because marginal cost falls as output capacity rises. The fifth term is positive since residual input supply is increasing in price. The last RHS term, $1/\beta$, is also positive.

The effect of an increase in the dominant firm's output capacity on the equilibrium internal supply is ambiguous:

(14)
$$\frac{dx_c}{dk} = \frac{1}{|\mathbf{H}|}\left[\left[\frac{p - c'(\cdot)}{\beta} - w_m\right]\frac{\partial^2 x_{rs}(w_m)}{\partial w_m^2} - 2\frac{\partial x_{rs}(w_m)}{\partial w_m}\right]\frac{\partial^2 c(\cdot)}{\partial y \partial k}\frac{1}{\beta} \lesseqgtr 0.$$

The term $(p - c'(\cdot))/\beta - w_m$ is nonnegative. It is positive when the dominant firm is able to exert monopsony market power in the raw input spot market. The term $\partial^2 x_{rs}(w_m)/\partial w_m^2$ depends on the second derivatives of input supply and fringe processor input demand, and cannot be signed. Under certain conditions, however, expression (14) can be signed. If the dominant firm's residual supply is perfectly elastic, then it cannot exert monopsony market power, and $(p - c'(\cdot))/\beta - w_m = 0$. In this case, $dx_c/dk > 0$, so that an increase in the dominant firm's output capacity will expand its equilibrium internal input supply. The same comparative static result occurs when input supply $x_s(w_m)$ and fringe demand $x_d(w_m)$ are linear, so that their second derivatives and that of residual supply are zero. Furthermore, if the dominant firm's residual supply increases at a decreasing rate, then $dx_c/dk > 0$.

The effect of a change in the proportion of input supply firms which the dominant processing firm contracts with or purchases from (α) on the equilibrium external spot market input price (w_m) is ambiguous:

(15)
$$\begin{aligned}\frac{dw_m}{d\alpha} = \frac{1}{|\mathbf{H}|}&\left[\frac{\partial x_s^{-1}(\cdot)}{\partial x_c/\alpha}\frac{1}{\alpha} + \frac{\partial^2 c(\cdot)}{\partial y^2}\frac{1}{\beta^2}\right]\\ &\times\left[-\left(\frac{p - c'(\cdot)}{\beta} - w_m\right)\frac{\partial x_s(w_m)}{\partial w_m} + x_s(w_m)\right]\\ &+ \frac{x_s(w_m) - x_c/\alpha}{|\mathbf{H}|}\frac{\partial^2 c(\cdot)}{\partial y^2}\frac{\partial x_s^{-1}(\cdot)}{\partial x_c/\alpha}\frac{1}{\alpha}\left[\frac{\partial x_{rs}(w_m)}{\partial w_m}\right]\frac{1}{\beta^2} \lesseqgtr 0.\end{aligned}$$

Since $x_s(w_m) - x_c/\alpha = x_s(w_m) - x_s(w_c)$, and $w_c > w_m$, it follows that $x_s(w_m) - x_c/\alpha < 0$, and the second line in expression (15) is negative. So if

$$x_s(w_m) \le \left|-\left[(p - c'(\cdot))/\beta - w_m\right]\partial x_s(w_m)/\partial w_m\right|,$$

then $dw_m/d\alpha < 0$, and increases in the proportion of input supply firms with which the dominant processing firm contracts will reduce the equilibrium external spot market input price. This condition is more likely when the dominant firm's residual input supply rises linearly or at a decreasing rate and the firm is able to exert monopsony market power in the external spot market.

The effect of an increase in the proportion of input suppliers contracting with the dominant processor on contracted supply is also ambiguous:

$$(16)\quad \frac{dx_c}{d\alpha} = \frac{-1}{|\mathbf{H}|}\frac{\partial^2 c(\cdot)}{\partial y^2}\frac{\partial x_{rs}(w_m)}{\partial w_m}\frac{1}{\beta^2}\left[-\left(\frac{p-c'(\cdot)}{\beta} - w_m\right)\frac{\partial x_s(w_m)}{\partial w_m} + x_s(w_m)\right]$$
$$-\frac{1}{|\mathbf{H}|}\left[\left(\frac{p-c'(\cdot)}{\beta} - w_m\right)\frac{\partial^2 x_{rs}(w_m)}{\partial w_m^2} - 2\frac{\partial x_{rs}(w_m)}{\partial w_m}\right]$$
$$\times\left[\frac{\partial x_s^{-1}(\cdot)}{\partial x_c/\alpha}\frac{x_c}{\alpha^2} + \frac{\partial^2 c(\cdot)}{\partial y^2}\frac{x_s(w_m)}{\beta^2}\right]$$
$$+\frac{1}{|\mathbf{H}|}\frac{\partial^2 c(\cdot)}{\partial y^2}\frac{\partial x_s^{-1}(\cdot)}{\partial x_c/\alpha}\frac{x_c}{\alpha^2}\left[\frac{\partial x_{rs}(w_m)}{\partial w_m}\right]^2\frac{1}{\beta^2} \lesseqgtr 0.$$

Line four of this expression is positive, but the others are ambiguous. If

$$x_s(w_m) \le \left|-\left[(p-c'(\cdot))/\beta - w_m\right]\partial x_s(w_m)/\partial w_m\right|$$

and

$$\frac{\partial^2 x_{rs}(w_m)}{\partial w_m^2} < 0,$$

then $dx_c/d\alpha > 0$. The first expression is more likely to hold when the dominant firm's residual input supply is upward sloping and it is able to exert monopsony market power in the input spot market. The second inequality holds when the dominant firm's residual input supply is linear or increasing at a decreasing rate.

In sum, an increase in the dominant firm's output production capacity will raise the external spot market price for raw input. The other three comparative statics results depend on the dominant firm's ability to exert monopsony power and on the second derivative of its residual input supply. If residual supply is linear or increasing at a declining rate, then a rise in output capacity will increase internal contract quantity or raw input. If

$$x_s(w_m) \le \left|-\left[(p-c'(\cdot))/\beta - w_m\right]\partial x_s(w_m)/\partial w_m\right|,$$

then a rise in the proportion of input suppliers under contract to the dominant firm will decrease the equilibrium external spot market price. If both of these conditions hold, then the equilibrium internally produced raw input quantity increases with

α. Thus, with two restrictions imposed, all of the comparative statics results can be signed.

Determining the Optimal Backward Integration

In the above short-run model, the proportion of vertically integrated suppliers is exogenous. In the long run, α is a choice variable, set to maximize profits. Applying the envelope theorem and using the definition $x_{rs} = (1 - \alpha)x_s(w_m) - x_d(w_m)$, the optimal choice for α solves:

$$(17) \qquad \frac{\partial \pi^*}{\partial \alpha} = -\left[\frac{p - c'(\cdot)}{\beta} - w_m^*\right] x_s(w_m^*) - \frac{\partial}{\partial \alpha} \int_0^{x_c^*} x_s^{-1}(x/\alpha)\, dx - fc'(\cdot) = 0,$$

which can be rewritten as

$$(18) \qquad \begin{aligned} \frac{\partial \pi^*}{\partial \alpha} = & -\left[\frac{p - c'(\cdot)}{\beta} - w_m^*\right] x_s(w_m^*) \\ & + (x_c^*/\alpha) x_s^{-1}(x_c^*/\alpha) \\ & - \int_0^{x_c^*} x_s^{-1}(x/\alpha)(1/\alpha)\, dx - fc'(\cdot) = 0. \end{aligned}$$

Multiplying the RHS of equation (18) by α and rearranging then results in:

$$(19) \qquad \begin{aligned} \left[\frac{p - c'(\cdot)}{\beta} - w_m^*\right] \alpha x_s(w_m^*) = & \; x_c^* x_s^{-1}(x_c^*/\alpha) \\ & - \int_0^{x_c^*} x_s^{-1}(x/\alpha)\, dx - \alpha f c'(\cdot). \end{aligned}$$

The left-hand side of equation (19) is VMP_x less external spot market price, or profit from the dominant firm's use of a unit of raw input purchased in the external spot market times the contract input supply function evaluated at the equilibrium spot market price. This term represents the economic rent achieved by purchasing input in the spot market that the dominant firm could have produced internally. The first term on the RHS of equation (19) is the value to the firm of internally produced input, the second term is the negative of total variable cost of producing internal input, and the third term is the negative of incremental fixed costs incurred by contracting. Hence, the right-hand side gives the dominant firm's producer surplus from producing input internally net of incremental fixed costs associated with producing additional input internally. The firm chooses optimal α to equate the profit from external supply, gained through exertion of monopsony market power, with the profit, or increase in producer surplus net of contracting or acquisition costs from internally producing raw input.

Under the model assumption that integrated input suppliers (those under contract or purchased by the dominant firm) are paid the present value of the stream of per period initial rents, the dominant processing firm will not fully backward integrate so long as its residual spot market input supply is upward sloping and its VMP_x curve is downward sloping. A fully integrated dominant firm utilizes internally supplied input to equate internal VMP_x with internal marginal factor cost. However, if residual supply is upward sloping, by reducing α the firm can make a positive profit by acting as a monopsonist with respect to its residual supply. Hence, the dominant firm will not fully backward integrate into its input market as long as the monopsony profits to be made from external input purchases are larger than the lost efficiency gains from internal production less the cost of purchasing the capacity required to achieve those gains.

At the other extreme, the dominant firm will backward integrate until increased output production efficiency gains plus increased profits from monopsony power exertion equal the cost of obtaining increased internal input production capacity. The firm will backward integrate until the economic rents from purchasing input in the spot market which could have been produced internally equate with the producer surplus from internal input production net of incremental capacity costs.

Conclusions

In this analysis, we demonstrate both graphically and analytically some important implications of a dominant processing firm's backward integration into its input supply industry. Contrary to the competitive view that vertical integration does not have effects external to the integrated firm, we find that backward integration has a number of important market effects. First, with backward integration, a dominant firm potentially can benefit from efficiency gains of expanded output and from a price reduction for its externally purchased inputs. Second, with partial backward integration, total input use by the dominant firm rises. These results are consistent with those of Perry (1978b). Third, when the dominant firm partially integrates through long-term contracting, its contract price will be at least as high as the equilibrium external spot market price for inputs. Fourth, when the dominant firm backward integrates, the price that it pays for externally purchased inputs can be higher, lower, or equal to the price it would have paid had it not integrated, depending on the effects that integration has on its elasticity of input demand and on its residual supply elasticity.

A comparative statics analysis reveals several important implications of backward integration. An increase in output capacity raises both the equilibrium external spot market raw input price and the dominant firm's optimal internal raw input production. A rise in the proportion of input supply firms with which the dominant firm contracts results in a fall in the equilibrium external spot market price for raw input and a rise in the dominant firm's optimal internal raw input production.

Last, we investigate the dominant firm's backward-integration choice. We find that the optimal degree of integration results when benefits from residual spot market supply management to reduce the price of externally purchased raw input equals the dominant firm's net profit from internal production of raw input. We also find that backward integration will be partial so long as acquired input suppliers are paid the present value of the stream of initial economic rents, residual supply is upward sloping, and the dominant firm's input demand is downward sloping.

Many of the results of this model are consistent with empirical relationships uncovered in the recent PSA studies of the red meat packing industry. For example, Williams et al. and Ward et al. found (*a*) that beef processors paid higher prices for cattle procured through marketing agreements than for cattle purchased in the spot market, (*b*) that higher rates of capacity utilization are associated with increased use of captive supplies, (*c*) that plants with larger capacities make greater use of captive supplies, and (*d*) that larger plants paid more for fed cattle than smaller plants. Under a wide range of circumstances, each of these results is predicted by our analysis.

Evidence from both Ward et al. and Williams et al. suggests that the price paid for cattle procured through forward contracting is lower than spot market price. This seems at variance with our results. However, it may be that forward-contracted purchases should not be included in captive supplies. Captive supplies might be better defined as those inputs with production processes vertically integrated into the firm, which means that the firm has "ownership and complete control over neighboring stages of production or distribution" (Perry 1989, p. 186). Forward contracting provides risk sharing, but the firm does not have complete control over production decisions for these inputs. Sellers may be willing to accept a lower price to have some of the production risk assumed by the purchasing firm.

In the same PSA study, Ward et al. estimate that a 1% increase in a packer's inventory of cattle purchased through marketing agreements results in a 10–41¢ per cwt price decline in the cash market for fed cattle that day (p. 25). The evidence with respect to packer-fed cattle is mixed. Ward et al. report a 1% increase in a packer's inventory of packer-fed cattle is associated with changes in cash market prices varying from a 30¢ per cwt decline for a 14-day inventory increase to a 20¢ per cwt rise for a 28-day inventory increase (p. 25). Again, these empirical results are predicted by our model.

Our results illustrate that a dominant firm's backward integration into input markets can have important effects on market participants external to the integrated firm. Importantly, we show that captive supplies may be used as a potential source for market power exertion. While many of the results of our study are consistent with recent findings in the PSA meat packing industry studies, the applicability of our model extends to other agricultural sectors, like poultry, and to natural resource industries, like forest products, where large processing firms are partially backward integrated into their strategic input markets.

An important caveat to these results is that the depressing effects of backward integration by the dominant firm on spot market price may not be the strategic end of that integration, but rather one of many purposes of the firm or even a side effect of major objectives. The dominant firm may value input quality control, input delivery control, and/or risk reduction just as highly, and may vertically integrate to achieve these objectives. Regardless of the intent, a dominant firm's backward integration will likely have effects external to the firm.

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