Vertically Aligned vs. Open Market Coordination: Dominance or Co-Existence?

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Abstract

Will a more tightly aligned system become the exclusive coordination or governance system in the pork industry? The analysis shows that the packer prefers to source hogs from both an aligned market and an independent market. This result is because the packer, facing variability in the demand for premium pork, must balance the cost of higher quality aligned hogs and independent hogs against the states of nature for demand for the premium product.

Keywords

Pork Supply Chains, Vertical Alignment, Open Market Coordination, Product Variability, Risk.

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Supply chains have been a dominant focus of both academic research and business strategy in the food and agribusiness industries for the past decade. Much discussion, analysis and experimentation with various forms of vertical alignment using governance structures such as strategic alliances, joint ventures, contracts, and other non-open market arrangements has occurred.

The U.S. pork industry exemplifies this experimentation and transformation with more tightly aligned supply chains. The traditional organization of the hog production slaughter and processing system, characterized by independent producers and open-market coordination with packers, is being replaced with production and marketing contracts, and packer owned and operated hog production facilities.

The percentage of U.S. pork production under contract or vertical integration mechanisms rose from 11 percent in 1993 to 64 percent in 1999. As the use of contracts for coordinating production has grown rapidly, so has the complex nature of these contracts. Three general contract types have become widely used for pork production coordination with each sharing risks and rewards differently (Martin 1999a, Lawrence 1999, and USDA 1996). The three dominant types of marketing contracts that have emerged are formula price agreements, price window contracts and contracts based on cost of production (Martin 1999a and 1999b).

A critical argument for this tighter alignment in the pork supply chain is improved signaling to suppliers of the weight and leanness characteristics that are valued in the marketplace. In open market coordinated systems, actual hog flows, in terms of volume and quality characteristics may differ from what packer's desire. This mismatching is attributable in part to producers and packers having differing objectives. Furthermore, the lack of information in a coordination mechanism can result in misalignment for production of output-specific characteristics in the short-run (Cloutier). When the product flow does not coincide with the information flow from pricing signals, the system's profit may be sub-optimal, providing an opportunity to increase overall system profits by realigning product and information flows and incentives.

Vertical integration and coordination may occur for several additional reasons including stable supplies, better quality control, improved flow scheduling, and reductions in price risk (Paarlberg et al, 1999.) Several empirical studies have examined the structure and performance of various types of contracts and vertical integration in the pork industry including Hennessy and Lawrence (1999); Johnson and Foster (1999); Lawrence, Schroeder, and Hayenga (2001); Martin (1997); Martinez (1999); and Rhoades (1995). An additional motivation for interest in the implications of alternative vertical alignment or coordination systems is the recent debate and court case concerning captive suppliers (Smith, 2004). The policy debate and litigation has focused fundamentally on concerns about the disappearance of open market transactions in the pork and beef industries, and whether or not packers/processors can and are using "captive supplies" (both livestock they own and feed and animals under longer term contracting arrangements) as a mechanism to manipulate prices and thus exercise monosopy power.

Theoretical arguments and empirical analyses suggest that there are economic efficiency incentives to develop tighter linkages between suppliers and buyers in a supply chain. But will a more tightly aligned system become the exclusive coordination or governance system – i.e. does vertical coordination sufficiently dominate open market transactions between suppliers and buyers such that those who do not vertically align eventually lose market access. Will open access markets disappear? Or is there an optimal mix of vertically aligned and open market sourcing strategies such that both will co-exist, and what characteristics of suppliers and buyers would result in this co-existence? More specifically how do the interaction of different transactions costs with different coordination systems, variability in buyer demand for different quality attributes, variability in quality attributes provided by different suppliers, and cost structure of buyers and suppliers determine the optimal sourcing strategy and coordination system between suppliers and buyers?

Conceptual Model of Packer/Producer Supply Chain Link

Consider a market where Packer A works with two types of producers – those with long-term alignments with Packer A and independent producers. The long-term alignments are meant to reflect anything from contracts through outright ownership of the production facilities. Packer A faces demand for two products – premium pork and commodity pork. (For purposes of developing an analytical model, we abstract from the disassembly process of carcasses into primal cuts.) Demand for premium pork is perfectly inelastic, but the quantity demanded is not known for certain at the time the long-term alignments must be committed. Demand for commodity pork is perfectly elastic.

The aligned and independent producers produce animals suitable for producing premium pork and commodity pork in different proportions. The fraction of animals from an aligned producer that is suitable for premium pork is f_p^a, and the fraction from these producers that is only suitable for the commodity pork is $f_c^a = 1 - f_p^a$. The analogous fractions for the independent producer are denoted f_p^i and f_c^i. Premium inputs can be used to producer commodity pork, but the reverse is not possible. One of the selection criteria for the aligned producers is that they can produce animals suitable for premium pork more consistently. Thus, we assume that $f_p^a > f_p^i$. When Packer A acquires animals from either type of producer, they must purchase the entire distribution of animals – not just the ones suitable for producing premium pork.

For modeling purposes, the packer has lower and upper limits on the number of hogs that must be processed each week Q_l and Q_u. Within these bounds, Packer A must satisfy the demand for the premium pork product if possible. If they do not have sufficient supplies of quality animals to produce the premium pork, then they can purchase additional animals from independent producers. If they have excess supplies of quality animals to produce premium pork, then the excess premium pork must be sold in the commodity market. Denote the quantity of animals purchased from aligned producers by Q^a, and the quantity purchased from independent producers by Q^i. If demand for premium pork is denoted by D (expressed in animal equivalent units), then the quantity that must be purchased from independent producers is given by:

$$Q^i = \max\left\{\min\left[\max\left(D - f_p^a Q^a, 0\right) / f_p^i, Q_u - Q^a\right], Q_l - Q^a\right\} \tag{1}$$

If the price for premium and commodity pork are denoted by p_p and p_c, the costs of acquisition and processing for aligned and independent producers are denoted by c_A^a, e_A^a, c_A^i, and e_A^i, and if π_A denotes Packer A profits for a given realization of demand, then

$$\begin{aligned} \pi_A = {} & p_p \min\left[f_p^a Q^a + f_p^i Q^i, D\right] \\ & + p_c\left[f_c^a Q^a + f_c^i Q^i + \max\left(f_p^a Q^a + f_p^i Q^i - D, 0\right)\right] \\ & - (c_A^a + e_A^a) Q^a - (c_A^i + e_A^i) Q^i. \end{aligned} \tag{2}$$

The first term denotes the revenue for the premium pork. The next term denotes the revenue for commodity pork. Inside the square brackets for this term, the first expression is the quantity of commodity animals purchased from aligned producers, the second term is the quantity of commodity animals purchased from independent producers, and the third term is equal to any excess purchases of premium quality animals beyond what is needed to satisfy the demand for premium products. This term will only be positive in the cases where Q^i equals zero, indicating that no additional purchases to obtain more premium animals were necessary, and where purchases from aligned producers exceeded the premium needs. The final two terms on the right-hand side of the equation are the total costs for acquisition and processing of animals from aligned and independent producers.

Combining (1) and (2) yields

$$\begin{aligned}\pi_A = p_p \min\Big[& f_p^a Q^a + f_p^i \max\Big\{\min\Big[\max\Big(D - f_p^a Q^a, 0\Big)/ f_p^i, Q_u - Q^a\Big], Q_l - Q^a\Big\}, D\Big] \\ &+ p_c\Big[f_c^a Q^a + f_c^i \max\Big\{\min\Big[\max\Big(D - f_p^a Q^a, 0\Big)/ f_p^i, Q_u - Q^a\Big], Q_l - Q^a\Big\} \\ &\quad + \max\Big(f_p^a Q^a + f_p^i \max\Big\{\min\Big[\max\Big(D - f_p^a Q^a, 0\Big)/ f_p^i, Q_u - Q^a\Big], Q_l - Q^a\Big\} - D, 0\Big)\Big] \\ &- (c_A^a + e_A^a) Q^a - (c_A^i + e_A^i)\max\Big\{\min\Big[\max\Big(D - f_p^a Q^a, 0\Big)/ f_p^i, Q_u - Q^a\Big], Q_l - Q^a\Big\}\end{aligned}$$

(3)

From the expression (3), it begins to become apparent why the packer might benefit from having access to both the aligned and independent producers. When demand for premium pork is high, the packer can acquire hogs from independent producers to fill the demand quota. This acquisition may be costly due to the relatively large amount of commodity pork that the packer will have to purchase and dispose of, potentially at a loss.

The reason for the potential losses despite the assumed perfectly elastic demand for commodity pork arises because there is competition for the output of the independent producers. To reflect this phenomenon, we introduce a second packer, Packer B, who competes with Packer A for hogs supplied by the independent producers. Independent producers supply hogs to either Packer A or B in response to the offered prices net of delivery costs.

To reflect the spatial aspect of this competition, we consider the producers to be distributed uniformly between Packer A and Packer B, which are separated by distance *X*. Prior to aligned arrangements, the situation is as follows. Each producer is treated as having a single unit of animals to deliver, and a producer is identified by her distance to Packer A, which is denoted by *x*, where $0 \leq x \leq X$. If the cost of transport per animal per unit of distance is *d*, and if we denote the acquisition cost that Packer A pays by c_A^i and the acquisition cost that Packer B pays by c_B^i, then producer behavior is defined as follows. If $c_A^i - dx \geq c_B^i - d(X - x)$, then the producer delivers to Packer A, and otherwise delivers to Packer B. The critical distance such that producers closer to Packer A deliver to Packer A and producers further away deliver to Packer B is defined by:

$$x^* = \frac{1}{2d}\left(c_A^i - c_B^i + dX\right). \tag{4}$$

So if the total number of animals in the competitive acquisition area for Packers A and B is *KX*, then the total supply to Packer A is defined by:

$$S_A = \int_0^{x^*} K dx = \frac{K}{2d}\left[c_A^i - c_B^i + dX\right] \tag{5}$$

and the supply to Packer B is

$$S_B = \int_{x^*}^{X} K dx = KX - \frac{K}{2d}\left[c_A^i - c_B^i + dX\right]. \tag{6}$$

As one might expect, if the acquisition costs for Packers A and B are equal, then the supply to each packer is half of the total, or *KX*/2.

The choice of acquisition cost for Packer B is defined by the following profit maximization problem where the acquisition cost is restricted to be non-negative and no greater than the level that elicits the entire supply from the competitive acquisition region:

$$\underset{0\le c_B^i \le c_A^i + dX}{\text{maximize}}\ (p_c - c_B^i - e_B^i)S_B$$
$$= \underset{0\le c_B^i \le c_A^i + dX}{\text{maximize}}\ (p_c - c_B^i - e_B^i)\left\{KX - \frac{K}{2d}\left[c_A^i - c_B^i + dX\right]\right\} \tag{7}$$

which, assuming an interior solution, means

$$KX - \frac{K}{2d}\left(p_c + c_A^i - 2c_B^i - e_B^i + dX\right) = 0. \tag{8}$$

To find equilibrium acquisition costs for both Packer A and B, (8) is solved simultaneously with the condition that $S_A = Q^i$ and $Q^a = 0$ where S_A is defined by (5), and Q^i is defined by (1). The solution to this system is

$$c_A^i = p_c + \frac{4d}{K}\max\left\{\min\left[D/f_p^i, Q_u\right], Q_l\right\} - 3dX - e_B^i \tag{9}$$

$$c_B^i = p_c + \frac{2d}{K}\max\left\{\min\left[D/f_p^i, Q_u\right], Q_l\right\} - 2dX - e_B^i. \tag{10}$$

The acquisition cost for Packer A from independent producers is a random variable through *D*. This is the situation in the absence of an aligned market. To motivate the choice process by producers of whether to operate independently or to develop an aligned relationship with the packer, producers are additionally differentiated by their level of risk aversion. The nature of the aligned relationship is that Packer A provides aligned producers with a fixed payment, c_A^a. There is a critical level of risk aversion such that more risk averse producers prefer the aligned arrangement, and less risk averse producers prefer to remain independent. This risk aversion level satisfies the following equation:

$$c_A^a = E[c_A^i] - \frac{\rho}{2}Var[c_A^i] \tag{11}$$

where c_A^i is defined as in (9). Those producers that choose the aligned arrangement effectively leave the pool of producers where Packers A and B must compete. Thus, the model described in (4)-(9) must be adjusted by reducing K by Q^a. and reflecting that $Q^a \neq 0$ is possible in (1). The modified equations are as follows:

$$S_A = \int_0^{x^*} (K - Q^a)dx = \frac{(K - Q^a)}{2d}\left[c_A^i - c_B^i + dX\right] \tag{5'}$$

$$S_B = \int_{x^*}^{X} (K - Q^a)dx = (K - Q^a)X - \frac{(K - Q^a)}{2d}\left[c_A^i - c_B^i + dX\right] \tag{6'}$$

$$\begin{aligned} &\underset{0 \le c_B^i \le c_A^i + dX}{\text{maximize}}\ (p_c - c_B^i - e_B^i)S_B \\ &= \underset{0 \le c_B^i \le c_A^i + dX}{\text{maximize}}\ (p_c - c_B^i - e_B^i)\left\{(K - Q^q)X - \frac{(K - Q^q)}{2d}\left[c_A^i - c_B^i + dX\right]\right\} \end{aligned} \tag{7'}$$

$$(K - Q^a)X - \frac{(K - Q^a)}{2d}\left(p_c + c_A^i - 2c_B^i - e_B^i + dX\right) = 0 \tag{8'}$$

and

$$c_A^i = p_c + \frac{4d}{K}\max\left\{\min\left[D / f_p^i, Q_u\right], Q_l\right\} - 3dX - e_B^i \quad . \tag{9'}$$

Producers are assumed to choose the contract market compared to independent production, open access markets based on their expectations of future open market prices, and that contract arrangements do not impact open market prices or price variability. Total supply variability is not considered in this stylized version of the model. This allows for variability in demand by type of product and proportion of hogs sourced from independent versus contract producers depending on variability in souring costs to be isolated.

For purposes of illustration, we assume that D is uniformly distributed between some lower and upper bounds (i.e., over the interval $[D_l, D_u]$). The expected profits as defined in (3) with c_A^i defined as in (9') are calculated via Monte Carlo simulation. Results are presented in the next section. Sensitivities of the results are explored for changes in the variability of demand, changes in supply of live hogs, changes in the mean demand, changes in producer risk preferences, and changes in packer risk preferences.

Results

The Monte Carlo Simulation model is parameterized to reflect a typical Midwest packer with a slaughtering capacity of 14,500 head per day. Table 1 summarizes the inputs for the model. The packer is assumed to have contract relationships with producers who producea higher proportion of host that meet the premium product specifications (75 percent) than hogs purchased in the independent market (65 percent). Packer processing costs are assumed to be $41 per head for aligned hogs (Hayenga (1998)). The model assumes processing costs of $43 per head for independent hogs due to the increase in variability of independent hogs. The competing packer has processing costs of $44 per head. The cost of delivery is based on Lawrence and Vontalge (2001) at $1.65 per head for hogs furthest from the competing packer. The price of commodity pork was estimated at $188.00 per live hog equivalent based on Poray (2001). Premium pork product was assumed to be 10 percent higher than commodity pork at $208.80 per live hog equivalent. Other model parameters will be used as sensitivity variables and are described in the results that follow.

Table 2 summarizes the results from the simulation analysis. Initially the model will assume that there are 174,000 total hogs in the market from which the packer chooses to contract. The first group of results assumes that the producer and the packer are both risk neutral, profit maximizers. In the first line of results, the packer faces a uniform distribution of premium product demand that ranges from 32,625 head to 76,125 head. In this first scenario, the packer chooses to contract 32,874 head at a price of $145.07 per head. On average, the packer also purchases 45,722 head from the independent market with a standard deviation of 19,317 head. The average price of independent hogs is $139.94 with a standard deviation of $1.39. Expected profit is $1.28 million in this scenario. This first scenario indicates, clearly, that the packer in this stylized situation prefers to have both aligned and independent hogs in its sourcing portfolio.

The next two rows of Table 2 illustrate what happens to the packer's decisions and acquisition cost of hogs when the variability in premium pork demand is reduced. Both the upper and lower values of demand are changed in these scenarios so that mean demand of premium product remains constant. As variability is reduced, the packer chooses to increase the number of aligned hogs contracted and reduce the expected number of independent hogs purchased. The increase in contracted hogs also reduces the standard deviation of independent hogs purchased because there are fewer states of nature where the packer needs the independent hogs to fill demand for premium product. The contract price rises slightly to entice more hogs into the aligned situation. Despite the reduction in demand for independent hogs the expected cost of independent hogs actually rises because more hogs have been removed from the independent market and placed in the aligned market. Finally, the packer enjoys higher expected profits when the variability in demand for the premium product declines.

Lines four and five of Table 2 summarize the results of increasing the supply of hogs and increasing the expected demand of premium product respectively. When the supply of live hogs increases the packer increases the amount of hogs aligned and reduces the expected number of independent hogs purchased. The increase in supply of hogs lowers the cost of both aligned and independent hogs making it cheaper for the packer to entice hogs into the aligned market. Increasing demand while holding supply constant results in an increase in both aligned and independent hog purchases. However, there is a greater increase in the number of independent hogs purchased to meet the 10,000 head increase in premium demand. This is because the increase in demand causes aligned hog costs to increase faster than independent hog costs.

The three lines in table 3 labeled "Producer Risk Aversion" summarize the results when suppliers in the market place are differentiated by risk aversion. In this scenario, risk aversion, ρ, is assumed to be 1 for the most risk averse supplier. Each successive supplier added to the aligned market for the packer would have a slightly lower risk aversion coefficient causing the packer to pay more to entice the next supplier into the aligned market. In the extreme, the last supplier in the market would be risk neutral. This scenario reflects the value of eliminating the variability of market prices for the producer when they choose to enter the aligned market. When producer risk aversion is introduced, the price that must be paid to entice aligned production decreases. This causes the number of hogs to be aligned to increase when comparing to the first three lines of table 2. However, as the variability of demand for premium product declines the number of hogs the packer chooses to align actually decreases (the number of aligned hogs increased when producers where assumed to be risk neutral). This is because the marginal cost of aligning the next supplier is higher than in the risk neutral scenario because the next hog must be compensated for both the marginal transportation cost and the marginal change in certainty equivalent value.

The final three lines in table 3 introduce risk aversion to the packer's profit function. The packer is assumed to maximize the certainty equivalent value of profits from Myer's (1987) mean/variance approximation of the certainty equivalent value. For illustrative purposes, the packer's risk aversion coefficient is assumed to be 1. Supplier risk aversion is the same as in the last section. Thus, this scenario is best compared to the "Producer Risk Aversion" scenario. When the packer is assumed to be risk averse the number of aligned hogs is reduced and the expected number of independent hogs is increased. The cost of aligned and independent hogs is slightly lower in this scenario but the number of hogs demanded in total is similar to the number of hogs demanded in the producer risk aversion scenario. The risk averse packer scenario indicates the packer's desire to reduce the risk of having too many aligned hogs when demand is low. The risk averse packer is more willing to use the independent hog market to fill demand for the variable premium market despite the lower quality of hogs in the independent market. As the variability in the independent market declines, the risk averse packer will increase the number of aligned hogs and reduce expected purchases from the independent hog market.

Conclusions

The supply chain between pork packers and producers continues to move towards a more tightly aligned system. This research explored the packers desire to maintain a portfolio of aligned and independent pork production markets when facing a variable demand for premium products. Despite the fact that the quality of aligned hogs was assumed to be higher than hogs in the independent market, the analysis shows that the packer prefers to source hogs from both markets. There are two primary reasons for the desire to maintain both markets. First, the cost of aligned hogs is generally higher than the cost of independent hogs, reflecting the quality differential, and the need to attract producers from the independent market. Second, facing variability in the demand for premium pork causes the packer to face states of nature where demand maybe low relative to the number of hogs the packer chooses to align. If the packer aligns too many hogs, the cost of acquisition would be too high relative to the amount of production that would have to be sold in the commodity pork market. On the other hand, if the packer aligns too few hogs, then in states of nature where demand is high the packer has to compete heavily for independent hogs, driving up the cost of hogs in that market. The packer must seek a balance where the cost of aligned hogs and independent hogs is balanced again the states of nature for demand for the premium product.

Sensitivity analysis revealed a number of interesting results. In particular, increases in the supply of hogs causes the packer to increase the amount of aligned hogs at the expense of the number of independent hogs. But, increases in demand for premium pork, while increasing the packers demand for both types of hogs, actually increase the demand more for independent hogs. When producer risk aversion is introduced, the packer aligns more hogs at a cheaper price. But, the packer will align fewer hogs as demand variability declines. Finally, when the packer is assumed to be risk averse, the number of aligned hogs is generally lower because of the risk of having too many hogs aligned when demand for premium products is low. As the variability of demand reduces the packer chooses to align more hogs. Yet, in all sensitivities the packer continues to prefer to have an independent market available to minimize the cost of sourcing hogs and to reduce the risk of not having enough hogs to fill demand.

The model used in this analysis is highy stylized. As such, the results are reflective of the assumptions used. Further research is warranted to determine the impact of the variability in the number of hogs available in the market place. It is expected that this variability would increase the expected cost and variability of cost of acquiring hogs in the open market. This might lead to the packer choosing to align a larger number of hogs. Other research should be conducted to determine the impact of multiple product demands and the ability of the packer to segment, select, and sort various types of hogs to meet these multiple demands.

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Table 1. Exogenous Fixed Parameters

Variable Name	Variable Symbol	Value
Fraction of Independent Hogs that meet Premium Product Specifications	f_p^i	0.65
Fraction of Aligned Hogs that meet Premium Product Specifications	f_p^a	0.75
Delivers Costs per Head Per Unit of Distance	d	1.65
Processing Costs for Contract Hogs	e_A^a	41.00
Processing Costs for Independent Hogs	e_A^i	43.00
Processing Costs for Competing Packer	e_B^i	44.00
Price of Commodity Product (per head)	p_c	188.00
Price of Premium Product (per head)	p_p	208.60
Maximum Plant Capacity (Head)		101,500
Minimum Plant Capacity (Head)		32,625

Table 2. Impact of Changes in the Variance of Demand, Supply, Expected Demand, Producer Risk Aversion and Packer Risk Aversion

Lower Demand	Upper Demand	Supply of Live Hogs	Quantity of Aligned Hogs	Expected Quantity of Independent Hogs[1]	Cost of Aligned Hogs	Expected Cost of Independent Hogs[2]	Expected Profit
Risk Neutral Impact of Reducing Risk							
32625	76125	174000	32874	45722 (19317)	145.07	139.94 (1.39)	1278510
42625	66125	174000	33524	44972 (10436)	145.10	141.00 (0.75)	1297490
48125	60625	174000	33717	44750 (5551)	145.10	141.60 (0.40)	1303116
Increase in Supply of Hogs							
48125	60625	203000	36884	41095 (5551)	144.16	140.98 (0.34)	1364166
Increase in Expected Demand							
58125	70625	174000	35437	58150 (5551)	146.31	142.61 (0.41)	1446624
Producer Risk Aversion[3]							
32625	76125	174000	37077	40837 (19317)	144.54	139.61 (1.43)	1303183
42625	66125	174000	35790	42358 (10436)	144.81	140.84 (0.77)	1310667
48125	60625	174000	34919	43363 (5551)	144.95	141.52 (0.41)	1310040
Packer Risk Aversion with Producer Risk Aversion[4]							
32625	76125	174000	31421	47399 (19317)	144.32	140.05 (1.38)	1299906
42625	66125	174000	32742	45875 (10436)	144.69	141.05 (0.75)	1309707
48125	60625	174000	33302	45228 (5551)	144.89	141.62 (0.40)	1309768

[1]Numbers in parantheses are the standard deviation of independent hogs purchased by the packer.

[2]Numbers in parantheses are the standard deviation of the price of independent hogs.

[3]The Risk Aversion Coefficient is different for each producer and ranges from 0 to 1 uniformly across the total units of hogs in the market.

[4]The Packer is assumed to maximize the mean/variance approximation of its certainty equivalent with a risk aversion coefficient of 1.