Estimated Value of Non-Price Vertical Coordination in the Fed Cattle Market

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EXECUTIVE SUMMARY

Economic gains appear to be possible for both cattle feeders and packers with improved coordination of the flow of cattle from feedlots to packing plants. From the packer's viewpoint, estimates made in this study indicate that a steady daily flow of cattle into their plant, a flow that is near their optimal processing capacity, will allow them to process cattle $2 to $5/head cheaper than is currently the norm for the industry. Estimates made indicate that packers could also save about $1/head if they could remove the fluctuations they experience in day-to-day slaughter rates. USDA data show that daily slaughter rates typically vary in beef processing plants by about 15 percent from day to day. In addition, it is estimated that packers can cut costs significantly by running within 5 percent of their optimal capacity rate. Five percent under-utilization of a plant costs the packer about $1/head. Ten percent under-utilization costs about $2.00/head and 15 percent under-utilization costs about $5.00/head (see Table 7).

From the feedlot's perspective, being able to market cattle when they are ready has value. Growth/cost of gain simulators and serial slaughter data (which were used to determine how yield grades and quality grades change with slaughter weight and days on feed) indicate that the ability to sell cattle within one week of their optimal sales date can be worth $2 to $12/head. Estimates indicate that feedlots have about a two-week window to market cattle effectively. Within this window, profits do not change by more than about $1/head given a stable cash market. Avoiding the marketing of overweight cattle avoids heavy discounts for over-done cattle and the feed conversion inefficiency that is suffered when cattle are held too long. Typically, holding cattle about one week beyond the window reduces potential profit by about $2/head, and holding them two weeks beyond the window reduces the maximum potential profit by over $5/head. Selling cattle a week ahead of the window (i.e., "green") typically results in about a $6/head loss. Selling them two weeks before the start of the window nets nearly a $12/head reduction in potential profit. It should be noted that these estimated costs of non-optimal slaughter dates depend partially upon the market-determined discounts for undesirable carcass characteristics. Therefore, they will vary somewhat over time.

The magnitude of profit potential estimated to arise from the timely exchange of cattle between feedlots and packers appears to provide strong incentives for packers and feedlots to coordinate the timing of the flow of cattle to their mutual benefit. However, study with a fed cattle market simulator shows that there are some natural conflicts in doing this that call for more than simple contracting arrangements between packers and feeders. The simulator used to analyze these conflicts is designed such that it can be operated by actual participants assuming management roles in eight simulated feedlots and four simulated packing plants, or it can be run totally by computerized/formula-controlled marketing arrangements. The simulator, by necessity, simplifies the fed cattle market to some degree, but the results are believed to be useful in analyzing the types of vertical coordination strategies needed to improve industry-wide profits and in determining the magnitude of potential profit improvements associated with such strategies.

Five industry-wide vertical coordination strategies were tested in the simulator. In general, the simulator showed that feedlots should and do prefer strategies that sell cattle light (i.e., early in the marketing window). Such strategies keep feed efficiency high and the volume of beef on the market in terms of total pounds relatively low. On the other hand, the simulator showed that strategies that generate a steady volume of relatively heavy cattle—that is, cattle at weights above the optimal weight sought by feedlots—favor packers. By keeping feedlots "backed-up," packers assure themselves of a large potential volume of cattle and thus an enhanced ability to operate at their optimal volume. These results are not surprising. They mirror the common belief in industry that there is an incentive for packers to "back cattle up," while there is an incentive for feedlots to "keep their showlist current" (if indeed not a bit beyond current).

The power of the simulator is its ability to look at the cost implications of these conflicting vertical coordination strategies. In comparing the strategy that was most favorable to packers versus cattle feeders, the packer-favoring strategy resulted in the lowest processing cost/head. However, this strategy raised the cost of gain to feedlots by $25/ head or about $.037/pound, and it increased the price discounts received/head (mostly due to more yield grade 4 discounts) by about $9/head, which translates to about $.008/pound. On the other hand, the strategy that favored cattle feeders resulted in the lowest cost of gain and least quality discounts for feedlots but raised packer processing costs by $2/head. The strategy favoring feeders also cut the volume of meat processed by nearly 6 percent and thus increased beef prices by about 4 percent relative to the strategy favored by packers. However, neither of these extreme strategies resulted in the highest total industry profit, (i.e., feedlot plus packer profit per head). The strategy that favored packers actually lost money for the total industry. The strategy that favored feedlots made approximately $22/head. If allocated equally, this would permit an added $11/head of profit for both packers and feeders.

A third strategy that neither minimized processing cost nor cost of gain and quality discounts generated the highest total industry profit. *It resulted in nearly $37/head of added profit under the same supply and demand conditions as the previously discussed strategies that favored either feeders or packers.* This strategy called for packers to receive their optimal volume of cattle when possible, but the strategy never sold cattle above the feedlot's optimal selling weight. The strategy required the anticipation of "gluts" of cattle (i.e., numbers in excess of the combined industry-wide optimal packer volume). The response to such anticipated gluts was to sell cattle early at somewhat lighter than optimal weights in order to avoid selling overweight cattle and volumes of cattle in excess of the packers' needs at a later date.

Allowing people to operate the simulator confirmed that natural conflicting interests do not lead to optimal industry vertical coordination strategies. Profits achieved when participants operated the simulator in an open market environment averaged only about $12/head compared to the $37/head of profit achieved with the best simulated vertical coordination strategy. In reality, profits can likely not be increased through improved vertical coordination by $37/head because of the added cost of negotiating and administering vertical coordination strategies and the need for a large percentage of the industry to use similar contracting arrangements. Likewise, what can be done in the controlled environment of a simulator cannot be perfectly duplicated in a more complex real industry setting. However, the cost savings estimates made here, as well as the simulations, suggest that improved vertical coordination through various contracting methods has the potential to add $5 to $15/head of industry-wide profit. Exactly how these enhanced profits would be shared between feeders and packers is dependent upon the terms of the vertical coordination/contracting agreement used, but there appears to be ample potential for both feeders and packers to benefit. *What is clear from this study is that non-price vertical coordination of the flow of cattle from feedlots to packers through contracting and other forms of agreement has the potential to be a positive activity for both feeders and packers*, rather than a strictly negative activity as is currently feared by some cattle feeders.

This study did not progress to the point that it could recommend specific vertical coordination strategies that would benefit both feeders and packers. However, it defined several basic attributes that appear to be essential for successful strategies. The vertical coordination strategies with the best potential, based on the strategies simulated here, appear to be those that utilize the day-to-day marketing flexibility that feedlots have (due to their approximately two-week marketing window) to stabilize the short-run flow of cattle into packing plants. In return, packers must make concessions to feedlots over a longer run to avoid extreme gluts of cattle and to keep slaughter weights down. In an ideal world, this would require industry-wide knowledge of current showlist sizes as well as knowledge of the approximate number of cattle coming onto the showlist over the next several weeks. This knowledge would then need to be utilized to make advanced commitments/plans for purchase/slaughter rates nearly a month in advance. In a less than ideal world, it would seem to imply some type of commitment from packers to assist feedlots in remaining "current."

The economic incentives for coordinated flows of cattle through the feedlot and processing phases are very strong. Non-price means of achieving stable flows of cattle are likely to persist and they may grow and expand over time.

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Introduction

Every agricultural product sold in a retail market must first go through a number of intermediate steps in reaching that market. Vertical coordination is a broad term referring to all of the methods by which activities at various stages of the production/marketing chain are "harmonized" (Mighell and Jones). In the past, and even today in many parts of the world, it is not unusual for all of these activities to be carried out by the same person or family. In modern developed economies, however, different people or different firms often perform different functions in converting raw commodities to finished goods.

Traditionally, in modern market economies, price has been the coordinating mechanism. Price signals originating with consumers are passed from firm to firm down the marketing chain until they reach producers. As early as 1959, Collins noted that the price system was, in some industries, proving to be inadequate as a means of coordinating the activities of various stages of the marketing chain. He argued that prices may not provide clear enough signals to efficiently direct economic activity when decisions made at one stage of production affect the performance of successive stages. Barkema points out that the inability of prices to transmit detailed information is an even greater problem in the modern food market due to increased consumer demands for more specialized food products. Examples of coordination through non-price means can be found in virtually every sector of the agricultural industry; however, the most dramatic examples of non-price coordination are in the livestock sector. Non-price coordination in the poultry industry has been extensive. Every level of production and marketing from farmer to retailer is coordinated through direct ownership (vertical integration) or contracting. In the last decade, the pork industry has also witnessed a significant increase in the use of non-price coordination methods.

The beef industry has not embraced non-price coordination to the same extent as the poultry and pork industries. While the beef industry has undergone dramatic changes in the last 20 years, these changes have had more to do with the consolidation of firms within the packing and feeding sectors than with changes in the nature of the interface between the sectors (Barkema and Drabenstott). Coordination between the various levels of the beef industry is still achieved primarily by the price system. Because of the adversarial relationship between feeders and packers, coordination between these levels (or more specifically the lack of coordination) may contribute to inefficiency. Inefficient coordination increases costs and results in greater risk for beef industry participants. The effect, therefore, of inefficient coordination is to reduce the competitiveness of the beef industry in relation to the more efficiently coordinated poultry and pork industries. Due to the competitive pressure from poultry and pork, it would be extremely useful for beef industry participants to know the potential benefits (in terms of industry-level profits) of improving coordination between the feeding and packing sectors.

In addition to these applied considerations, a study of vertical coordination in the fed cattle market has compelling theoretical justification. The economics literature discusses the nature of, causes for, and conceptual benefits from vertical coordination via non-price methods. However, since economists rarely have the opportunity to measure performance criteria for various forms of vertically coordinated structures, empirical estimates of the value of coordination are noticeably absent in the literature.

Similarly, there are no estimates of whether one set of parties (buyers or sellers) or both gain or lose, and how much one set gains or loses relative to the other. As Den Ouden *et al.* note:

> In spite of the extensive descriptive literature on the potential benefits and costs of improved vertical coordination, there seems to be little quantitative information on its effects both at the overall level of the chain and with respect to the individual stages (p. 287).

The objective of this research is to determine the value of coordinated marketing/purchasing between cattle feeders and meatpackers. Two separate effects of non-price coordination will be noted. First, this research will determine how industry-wide profit is affected by the employment of various non-price coordination strategies. If profits can be increased by the use of non-price coordination, then the incentive to adopt such strategies exists. The second step in this research will be to determine how the different coordination strategies considered will affect the costs of both feeders and packers. For non-price coordination to be an attractive option, costs must be reduced on both sides of the market.

To accomplish the goals of this study, data generated in a semester long session of the Fed Cattle Market Simulator (FCMS) will be used (Koontz, *et al.*). A comparison of the industry profits actually realized in the simulation will be compared with those which could have been realized using relatively simple "rule-of-thumb" coordination strategies based on slaughtering the volume of cattle that packers desire and/or the weight of cattle that feedlots desire.

Vertical Coordination Background and Theory

The fact that prices convey information imprecisely provides an incentive for firms to implement non-price methods of coordination. Many authors have explored the incentives to adopt non-price coordination methods. Among them, Frank and Henderson cite "asset specificity" as an incentive for vertical coordination. This incentive appears to be particularly relevant to the fed cattle market. Asset specificity refers to the fact that much of the capital used in a productive process may have no alternative uses. Consequently, costs rise rapidly if these assets are unemployed or underemployed. Contracting for scheduled delivery of raw materials can help to avoid this situation.

Frank and Henderson build on the theory of Williamson, which divides investments into three categories: nonspecific, mixed, and idiosyncratic. Idiosyncratic investments have very specific uses. Conversely, nonspecific investments can be put to a number of different uses. Mixed investments fall somewhere on a continuum between these extremes. Williamson argues that contracting will be the cost minimizing method of coordination between levels when recurring transactions occur between participants whose investments are mixed. As the characterization of investments becomes more idiosyncratic, direct ownership (vertical integration) becomes the cost minimizing coordination method.

The foregoing discussion of the incentives for vertical coordination is a useful starting point for investigating non-price coordination in the fed cattle market. All of the incentives offered by the various authors discussed here are present to varying degrees in the fed cattle market. Williamson's focus on idiosyncratic investment is particularly relevant given the fed cattle market structure that has emerged over the last 15 years. The largest packing firms have invested in large plants that must run at full capacity or face steep production cost increases. Koontz and Purcell note that because of their relatively high ratios of fixed to variable costs, packers have strong incentive to operate at full capacity in order to minimize per unit costs. Schroeder *et al.* point out that several of the incentives for packers to contract also apply to feeders. For example, contracting allows feeders to reduce risk, to obtain more favorable financing terms, and to ensure a buyer for their cattle.

Still, non-price coordination is not carried on in the fed cattle market at the levels observed in other livestock markets. Part of the difference in market structure between different livestock markets can be explained by the biological differences between livestock (Ward). For example, cattle production is subject to much longer production delays than either poultry or pork production. In addition, cattle production relies on the ability of cattle to consume forages. This makes cattle production much more land-intensive than other types of livestock production. *However, the lack of non-price coordination in the fed cattle market must, to some degree, be attributed simply to the reluctance of market participants at different levels to cooperate with one another.* The current furor over captive supply levels is evidence of the adversarial relationship between feeders and packers.

This adversarial relationship should not be surprising to economists. Perry writes that when the investments of participants on one or both sides of a transaction are idiosyncratic, "opportunistic behavior" is likely to result. Such behavior consists of trying to extract all of a trading partner's profit by, for example, threatening to dissolve the trading relationship. The presence of opportunistic behavior makes cooperation between the two groups more difficult to achieve; however, *it also indicates that the potential gains from cooperation may be substantial. This research is concerned with quantifying these potential gains*. As noted, empirical studies of the effects of vertical coordination are virtually nonexistent. This study thus represents an important addition to the vertical coordination literature.

Fed Cattle Market Simulator Background

Data for this experiment were collected in the spring 1995 semester when the FCMS was run as a semester-long undergraduate class at Oklahoma State University. As the name suggests, the FCMS simulates the real-world fed cattle market. Participants are divided into 12 teams consisting of from two to four members. Eight teams role-play as feedlot managers, and four teams role-play as packing plant managers. The teams interact to trade simulated pens of fed cattle. Face-to-face negotiation between feedlot and packing plant teams determines the fed cattle price in the FCMS.

Trading in the FCMS takes place in six-to-eight minute periods which correspond to a week of real time. At the beginning of each of these simulated weeks, feedlot teams receive a set of cards representing cattle entering the showlist. Each card represents one pen consisting of 100 head of 1,100-pound cattle. Each week that the cattle aren't sold, they gain 25 pounds. If cattle are not sold by the end of the week in which they weigh 1,200 pounds, they are automatically sold to an anonymous packer for a large discount beginning at $5/cwt below that week's average price.

The two largest costs faced by feeders are the purchase cost of feeder calves and feed costs. Purchase costs are exogenous to the FCMS, which means they are determined outside of the simulator. Feeders receive a predetermined number of 700-pound feeder animals at a predetermined price. Ration/feed costs are set exogenously; however, cost of gain depends to a large extent on the actions of the feedlot managers. Cost of gain for 1,100 to 1,150-pound cattle can be calculated simply as pounds of gain times ration cost per pound of gain; however, as cattle reach weights in excess of 1,150 pounds, they begin to incur cost of gain penalties reflecting the fact that heavier cattle convert feed less efficiently than lighter cattle. The penalty for 1,175-pound cattle is 8 percent of the total cost of gain and for 1,200-pound cattle it is 18 percent of the total cost of gain. To illustrate, the feed cost for a 1,200-pound animal in the FCMS would be calculated as follows:

$$[(1{,}200 \text{ lb.} - 700 \text{ lb.}) \bullet (RC \bullet 1.18)], \quad (1)$$

where

RC is the ration cost per pound of gain.

The weight of cattle also has an important effect on the prices which feedlots receive for their cattle. Packers discount for three important carcass characteristics when calculating bid prices. These factors are percent of carcasses grading Select, percent of yield grade 4 and yield grade 5 carcasses, and percent of carcasses which are too light or too heavy. The sum of these discounts is the smallest for 1,150-pound cattle. Table 1 shows the carcass characteristics assumed for the five weight classes of cattle in the FCMS along with discount factors used by packers in calculating bid prices.

Table 1. Carcass Characteristics and Price Discounts in the FCMS

Slaughter Weight	% Select	% >YG3	% Light Carcasses	% Heavy Carcasses	Dressing Percentage
1200	25.0	8.00	0.0	10.0	64.0
1175	29.0	6.33	0.0	5.0	63.5
1150	33.0	4.66	0.0	0.0	63.0
1125	37.0	3.00	5.0	0.0	62.5
1100	41.0	1.37	10.0	0.0	62.0
Discounts	\$5/cwt	\$10/cwt	\$2/cwt	\$2/cwt	

Note: Discounts are based on carcass price per hundredweight

On the packer side, cost is a function of the number of pens slaughtered each week. Each firm faces a U-shaped short-run cost curve. These weekly cost curves were developed for the simulator based on research by Duewer and Nelson. Each curve is different, reflecting the different sizes of the packing plants in the simulator. The optimal weekly slaughter size for the smallest packer is 800 head and for the largest is 1,200 head. The other two plants have optimal weekly slaughter rates of 900 and 1,100 head. Because of the shape of the cost curves, any deviation above or below these optimal slaughter rates results in increased costs for the packers. Table 2 reports the short-run cost curves for each plant in the FCMS, and Figure 1 illustrates the shape and relationship of the four curves.

Marketing decisions affect packer profitability through returns as well as through costs. This is due to the manner in which boxed beef price is determined in the simulator. Weekly boxed beef prices are specified as a function of slaughter levels for the past nine weeks. The average boxed beef price is \$120/cwt and is based on an average slaughter level of 40 pens of 1,150-pound cattle, which is the sum of the four packers' optimal slaughter levels. Deviations from this slaughter level alter the boxed beef price according to a distributed lag of price flexibilities. Given this boxed beef demand specification, slaughtering a larger than optimal number of pens of cattle not only increases packer costs but also reduces packer revenue through the behavior of boxed beef prices. Slaughtering cattle weighing more than 1,150 pounds will also depress boxed beef price by increasing the total pounds of beef on the market. Figure 2 graphs the long-run boxed beef demand function used by the FCMS, that is, the price that will result from nine consecutive weeks of slaughtering a given number of pens. Figure 3 graphs the weekly and cumulative distributed lag pattern for the boxed beef price flexibilities, which reveals the impact of a given lagged slaughter level on boxed beef price. The distributed lag model depicted in Figure 3 was econometrically estimated by Meyer.

Table 2. Processing Costs per Head for FCMS Packing Plants

Pens Processed/Week	Packing Plant Number 1	2	3	4
1	332.52	329.09	324.10	322.00
2	181.68	178.26	173.26	171.40
3	131.41	127.98	122.98	121.12
4	106.27	102.84	109.58	111.83
5	87.95	91.93	98.45	101.44
6	77.56	81.29	88.48	91.93
7	70.91	73.20	79.86	83.46
8	68.56	68.06	72.80	76.18
9	71.10	66.27	67.51	70.25
10	79.10	68.19	64.19	65.83
11	93.13	74.20	63.03	63.06
12	100.00	84.80	64.25	62.10
13	100.00	100.00	68.05	63.11
14	100.00	100.00	74.63	66.24
15	100.00	100.00	84.20	71.64
16	100.00	100.00	96.95	79.47
17	100.00	100.00	100.00	89.88
18	100.00	100.00	100.00	100.00

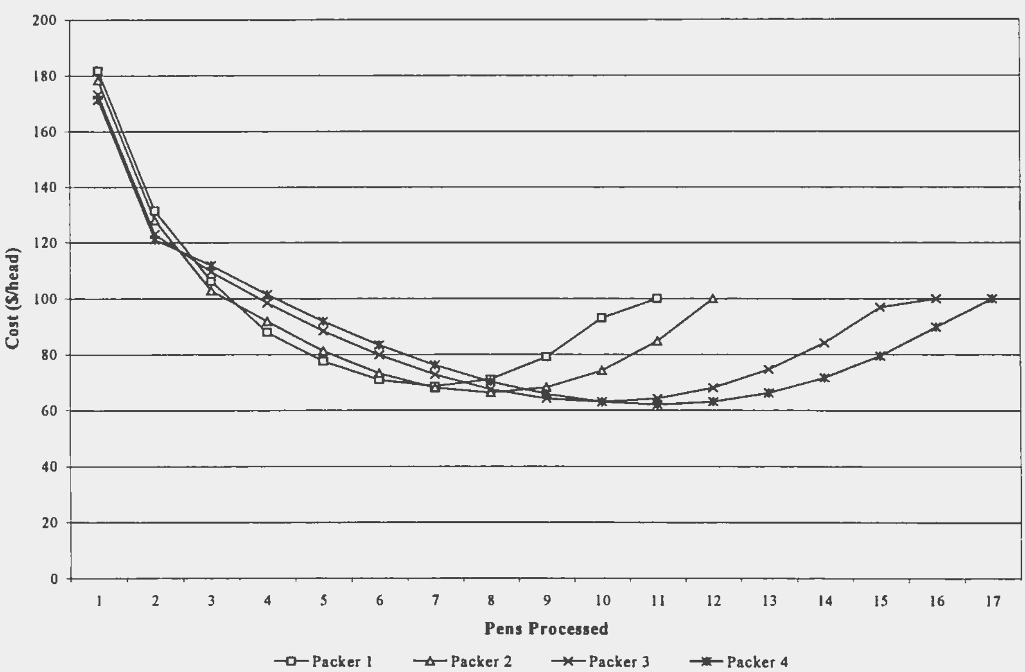


Figure 1. FCMS Packing Plant Short-Run Average Total Cost Curves

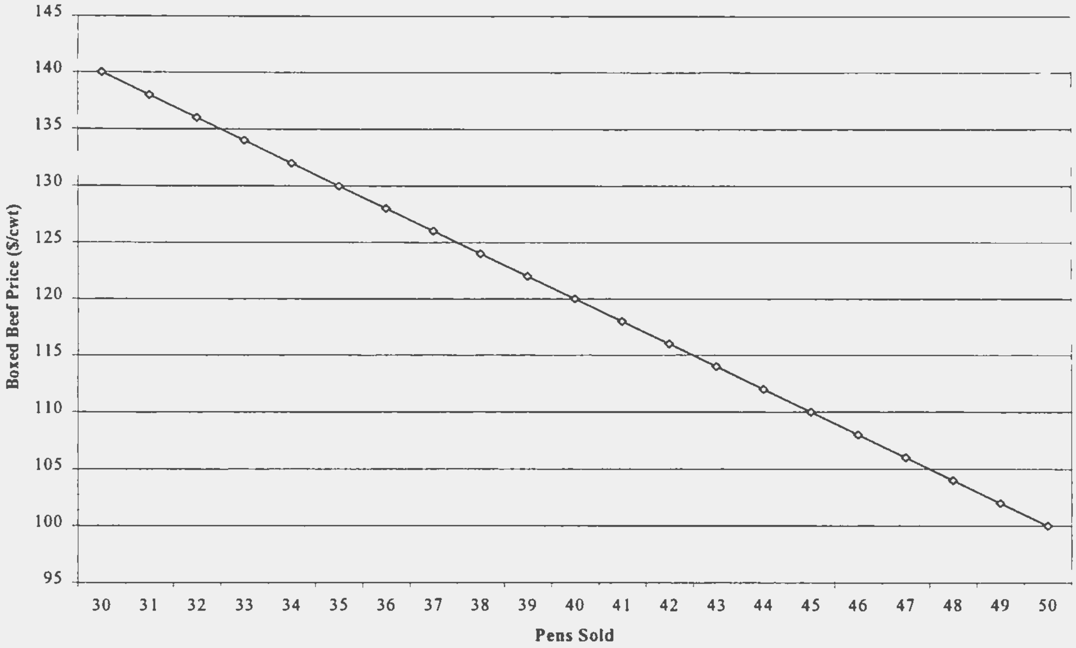


Figure 2. Boxed Beef Demand Schedule Used in FCMS

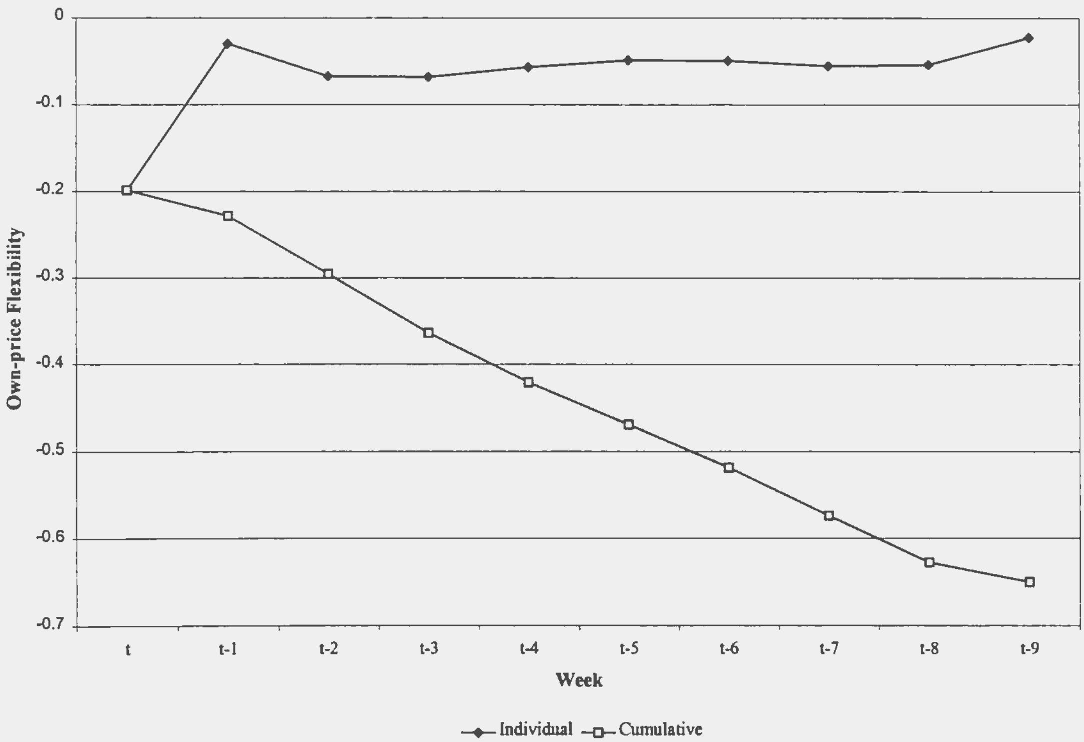


Figure 3. Distributed Lag of Boxed Beef Price Flexibilities Used in the FCMS

Vertical Coordination Simulation Methods

In this study, packer and feeder profits from the spring 1995 FCMS course will be compared to profits obtained using simple non-price coordination strategies. Consideration of FCMS structure as outlined above suggests that strategies which minimize feeding inefficiencies and slaughter/fabrication costs, have some potential for improving industry profits. Thus, coordination strategies examined in this study will focus on marketing cattle at minimum cost of production weights (i.e., 1,150 pounds) and marketing as close as possible to an optimal number of pens per week for packing plant efficiency (i.e., 40).

In order to perform the simulation required to make comparisons necessary for this study, a spreadsheet was developed which calculates aggregate weekly feedlot and packer costs and weekly boxed beef prices based on the number and weight of cattle sold each week. Since all feedlots face identical costs (i.e., they all buy cattle at the same price and have the same cost-of-gain), aggregating feedlots simply involved summing the number of pens marketed at each weight each week and calculating costs for each weight group as illustrated in equation (1).

Aggregating packers was somewhat more difficult since each packer faces a different short-run cost curve. The solution to this problem involved creating an aggregated cost schedule within the spreadsheet used for simulation which contains the cost incurred by each packer from the slaughter of a given number of pens. Such a schedule is given in Table 2. Using this aggregated industry schedule, the least-cost distribution among packing plants of any number of pens could be determined. Using this aggregation procedure for packer costs, it was only possible to consider total weekly slaughter figures rather than each packer's weekly slaughter level. This method of aggregation assumes that weekly slaughter is distributed among packers in a least-cost manner; however, this is certainly not always the case in reality or in the simulations with live participants. Thus, *this method understates packers' costs*. The costs resulting from individual packers slaughtering a non-optimal number of pens will be removed in this analysis.

In this experiment, the flow of fed cattle generated by FCMS participants was entered into the spreadsheet simulator. This simulation generates the industry profit totals shared by feeders and packers. This flow of fed cattle was then varied within the spreadsheet according to five simple coordination rules. The total number of cattle marketed was not changed: the same number of cattle was used in each simulation, but the timing of marketings was varied, which also resulted in the weights and individual weekly volumes changing.

Non-price Coordination Strategies

Data on marketings from weeks 29 through 98 from the FCMS were used to establish baseline profits in the simulation spreadsheet. Costs and returns from this simulation were compared to five simple non-price coordination strategies. All of these strategies represent variations on the premise of minimizing production costs. For feeders, this amounts to avoiding the extra feeding costs that result from marketing cattle at weights above 1,150 pounds. For packers, it amounts to avoiding the extra processing costs which result when slaughter plant volume is not equal to 40 pens and avoiding price discounts which result from the purchase of cattle at weights other than 1,150 pounds. In addition, each strategy impacts industry profits through its effect on the total volume of boxed beef produced and the boxed beef discounts received (see Table 1).

The first strategy was to market 40 pens each week. This strategy avoids all excess processing costs by keeping packers always at the lowest point of the aggregated cost curve. In order to ensure a sufficient supply of cattle on the showlist to meet the 40-pen requirement, cattle must be marketed at heavier weights. This strategy should therefore generate considerable feeding inefficiencies. In addition, the increase in the marketing of heavy cattle will depress the boxed beef price due to increased quantity and quality discounts.

The second strategy was to sell all cattle at 1,150 pounds. This strategy avoids all costs associated with feeding inefficiency and price discounts for undesirable (heavy) carcass characteristics. The strategy is simple to implement. Each week, all pens of cattle weighing 1,150 pounds are marketed, regardless of how many pens this may be. Since marketings will seldom equal 40 pens, processing costs should increase under this strategy. On the other hand, by avoiding the slaughter of heavy cattle, this strategy should increase boxed beef price.

The third strategy represents a slight modification of the previous one. One-third of the cattle on the showlist weighing 1,125 pounds were sold each week, with the remaining two-thirds being sold the following week at 1,150 pounds. This strategy attempts to maintain a more consistent flow of cattle than the previous strategy—thereby reducing processing costs. The choice of one-third as the proportion of 1,125-pound cattle to slaughter is arbitrary. It is possible that selling some other fraction of cattle earlier would be as effective or even more effective in reducing processing costs. This strategy should also increase the boxed beef price due to the slaughter of some lighter cattle.

The last two strategies are quite similar and represent compromises between the first two. Strategy four was to sell 40 pens per week or less (if 40 weren't available) at weights between 1,125 and 1,175 pounds. The least cost slaughter volume is specified as a target; however, cattle may not be slaughtered at extreme weights in order to reach that target. The fifth strategy was to sell 40 pens per week or less (again, if 40 weren't available) at weights at or below 1,150 pounds. In each of these strategies, the costs of non-optimal marketings will be shared by packers and feeders. In strategy 5, though, boxed beef price should increase significantly since a substantial number of light (i.e., less than 1,150 pounds) cattle will be slaughtered.

Simulation Results

Table 3 presents total costs and returns from the simulations along with information on the volume of cattle and boxed beef traded under each of the non-price coordination strategies. Table 4 presents the cost and return data on both a per-head and per-hundredweight of boxed beef basis. *It is important to view the results on a per-unit basis since each of the coordination strategies results in slightly different volumes of cattle and of boxed beef.* The selection of a relevant unit depends to some degree upon one's perspective. Feedlot managers would probably prefer to analyze their costs and returns on a per-head basis, while packing plant managers would probably prefer to view those figures per hundredweight of boxed beef. For this reason, results are presented both ways.

All but one of the non-price coordination strategies resulted in higher industry-level profits than those realized by FCMS participants. Strategy 1, consisting of always selling 40 pens, actually resulted in industry losses of $26.06/head ($3.56/cwt boxed beef). There are two reasons for this result. First, in order to consistently meet the 40-pen target, the showlist had to be kept full. To do this, cattle had to be held to high weights. This resulted in high price discounts and high feeding costs. In fact, this strategy resulted in the highest price discounts and cost of gain of any other strategy (including no coordination). Second, the high boxed beef supply resulting from the slaughter of a large number of heavy cattle pushed boxed beef prices down, further reducing industry profits. Boxed beef supplies were higher and prices lower under this strategy than any other. From the packer's perspective, however, this strategy is not all bad. Processing costs on a per-head and per-hundredweight of boxed beef basis were considerably lower under this strategy than under any other.

Table 3. Summary of Results of Simulation of Non-price Coordination in the FCMS

Strategy	No Coordination	1	2	3	4	5
No. Of Pens Sold	2,639	2,742	2,630	2,628	2,590	2,576
Ave. Sale Weight (cwt)	11.57	11.59	11.50	11.42	11.45	11.43
Boxed Beef Yield/hd. (cwt)	7.31	7.33	7.25	7.17	7.21	7.19
Boxed Beef Sold (mil. cwt)	1.93	2.01	1.91	1.89	1.87	1.85
Ave. Boxed Beef Price	123.05	119.56	123.73	124.50	125.73	126.30
Boxed Beef Rev. (mil.)	237.35	240.14	235.76	234.73	234.67	233.77
By-product Rev. (mil.)	25.96	27.01	25.71	25.50	25.22	25.03
Total Discounts (mil.)	4.43	6.65	4.04	4.08	4.01	3.99
Net Revenue (mil.)	258.88	260.51	257.43	256.16	255.87	254.81
Total Feeder Cost (mil.)	180.53	187.78	179.86	179.82	177.22	176.30
Total C.O.G. (mil.)	57.24	62.03	53.94	52.90	52.67	51.96
Total Processing Cost (mil.)	17.99	17.84	17.72	17.67	17.11	17.04
Total Profit (mil.)	3.12	(7.15)	5.90	5.76	8.88	9.51

Note: Coordination strategies 1 through 5 are as follows:

1) Sell 40 pens/week when available.
2) Sell all cattle at 1,150 pounds.
3) Sell 1/3 of the 1,125 each week and the remaining cattle at 1,150 pounds the next week.
4) Sell 40 pens or less at weights between 1,125 and 1,175 pounds.
5) Sell 40 pens or less at 1,150 pounds or less.

Table 4. Summary of Simulation Results on Per Head and Per Hundredweight of Boxed Beef Basis

Strategy	No Coordination	1	2	3	4	5
Boxed Beef Rev./hd.	899.41	875.79	896.43	893.19	906.05	907.50
By-product Rev./hd.	98.37	98.51	97.75	97.05	97.37	97.16
Discounts/hd.	16.80	24.24	15.36	15.51	15.48	15.49
Net Rev./hd.	980.98	950.06	978.82	974.72	987.93	989.17
Feeder Cost/hd.	684.07	684.84	683.89	684.23	684.24	684.40
C.O.G./hd.	216.92	226.23	205.11	201.31	203.36	201.72
Processing Cost/hd.	68.18	65.06	67.38	67.25	66.06	66.15
Profit/hd.	11.81	(26.06)	22.44	21.93	34.28	36.91
Boxed Beef Rev./ cwt boxed beef	123.05	119.56	123.73	124.50	125.73	126.30
By-Product Rev./ cwt boxed beef	13.46	13.45	13.49	13.53	13.51	13.52
Discounts/cwt boxed beef	2.30	3.31	2.12	2.16	2.15	2.16
Net Rev./cwt boxed beef	134.21	129.70	135.10	135.86	137.09	137.67
Feeder Cost/cwt boxed beef	93.59	93.49	94.40	95.37	94.95	95.25
C.O.G./cwt boxed beef	29.68	30.88	28.31	28.06	28.22	28.07
Processing Cost/ cwt boxed beef	9.33	8.88	9.30	9.37	9.17	9.21
Profit/cwt boxed beef	1.62	(3.56)	3.10	3.06	4.76	5.14

Note: Coordination strategies 1 through 5 are as follows:
1) Sell 40 pens/week when available.
2) Sell all cattle at 1,150 pounds.
3) Sell 1/3 of the 1,125 each week and the remaining cattle at 1,150 pounds the next week.
4) Sell 40 pens or less at weights between 1,125 and 1,175 pounds.
5) Sell 40 pens or less at 1,150 pounds or less.

The second non-price coordination method—sell all cattle at 1,150 pounds—resulted in a $10.63/head ($1.48/cwt boxed beef) increase in profits in comparison to no coordination. Nearly all of this gain was due to cost of gain reductions. Cost of gain decreased by $11.81/head ($1.37/cwt boxed beef) under this strategy. Net revenue was actually reduced slightly due to the lower volume of boxed beef sold. Processing costs were reduced; however, these costs were over $2/head ($0.88/cwt boxed beef) higher than under strategy 1, which always slaughtered 40 pens.

The third strategy—sell one-third of each age group of cattle at 1,125 pounds and the remaining two-thirds at 1,150 pounds the following week—was expected to reduce processing costs in comparison to the preceding strategy. On a per-head basis, it did exactly that; however, on a per-hundredweight of boxed beef basis, processing costs were higher under this strategy than under any other. The average boxed beef price did increase slightly over that from the previous strategy due to the lower boxed beef volume. This strategy had the lowest average live weight and carcass weight per head. On a per-head basis, results of this strategy—as expected—are similar to the previous strategy: industry profits increased by $10.12/head ($1.45/cwt boxed beef) over no coordination, with the bulk of that increase due to reduced cost of gain. Cost of gain was lower under this strategy than under any other.

The compromise strategies (four and five) worked quite well in increasing aggregate profits—both total and per unit of output. Compared with no coordination, strategy four increased industry-level profits by $22.47/head ($3.14/cwt boxed beef), and strategy five increased profits by $25.10/head ($3.52/cwt boxed beef). The effects of these strategies on costs and returns were very similar. Both resulted in higher net revenue than no coordination due both to increased boxed beef price and reduced price discounts. Both also reduced processing costs (per head and per hundredweight of boxed beef) over no coordination. The primary difference in these strategies is in their effect on cost of gain. Strategy 5 results in a lower cost of gain due to the fact that this strategy avoids the cost of gain penalty associated with 1,175-pound cattle.

BEEFGAIN Simulation

The parameter structure of the FCMS causes the cost of gain for heavy cattle to rise rapidly, that is, 8 percent for 1,175-pound cattle and 18 percent for 1,200-pound cattle. This reduces total industry profit. Likewise, as cattle reach heavier weights, the FCMS assumes that more yield grade 4 (Y4) and heavy weight carcasses are present. The FCMS discounts the boxed beef price received by packers by $10/cwt for Y4 cattle and $2/cwt for heavy carcasses. This results in an industry profit curve (i.e., profits to be divided between packers and feeders) by weight which rises from 1,100 pounds to 1,150 pounds and then declines. A key question is how realistic relative to actual market conditions is this pattern of relative profits by slaughter weight.

It should be noted that this profit is the combined profit of packers and feedlots. Figure 4 illustrates how industry profit/cwt appears graphically as the area between the break-even prices of feedlots and packers. If one assumes these profits to be shared equally at all weights (a big assumption), the profit pattern for feedlots will also be concave downward and will peak at 1,150 pounds for both the feedlot and packer.

Presumably, most of this decline in profits is suffered at heavier weights by feedlots; however, the spreadsheet simulation is not capable of distinguishing how the reduced profits are split between feedlots and packers. Actual profit distribution as generated with live simulations with the FCMS can be referenced to determine how profits/losses are shared by packers and feedlots for different weights of cattle.

Additional simulation to determine the effect on profits of under- or over-finishing cattle was also possible using BEEFGAIN, a feedlot gain simulator developed by animal scientists at Oklahoma State University (Gill and Burditt). This simulator calculates the physical as well as financial performance of cattle on feed based on parameters provided as input. In order to make comparisons between feedlot profits achieved at various slaughter weights, simulation of the feeding of 700-pound feeder steers to a series of different weights was conducted. Slaughter weights used in the simulation correspond to the slaughter weights used in the FCMS (i.e., 1,100 to 1,225 pounds in 25-pound intervals). A feeder cattle price of $74/cwt was used in the simulation. A fed cattle price of $69/cwt was used. This price was discounted according to the carcass characteristics expected at the different slaughter weights.

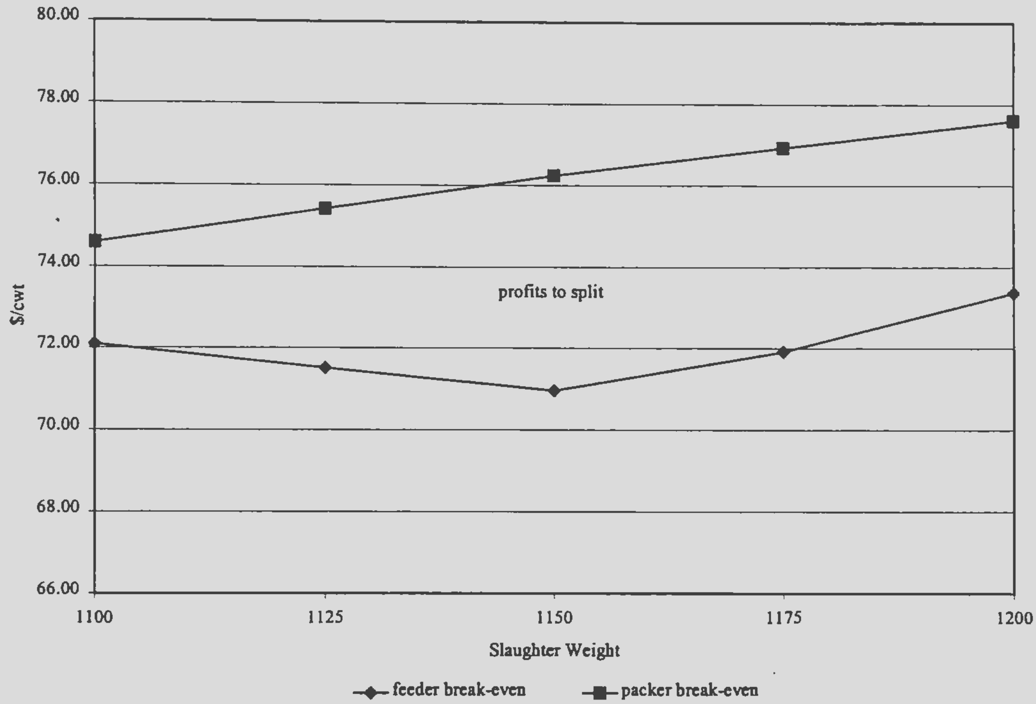


Figure 4. Graphic Representation of Industry-Level Profits in the FCMS

Two different fed cattle price-discounting regimes are compared in this study. First, carcass characteristics are not considered in setting price. In this simulation, all cattle receive the same price regardless of weight. The common price used is $67.75/cwt. This price was arbitrarily chosen. The price used in this simulation affects the level of profits but does not alter the relationship between profits and slaughter weight, which is the subject of this investigation. Second, carcass characteristics are based on the results of previous serial slaughter studies (Hicks *et al.* and Van Koevering *et al.*). These studies were designed experiments in which cattle of very similar physical characteristics were placed on feed together. All cattle received the same treatment throughout the feeding period. The cattle were divided into four subgroups which were slaughtered at 14-day intervals beginning with 100 days on feed. At slaughter, the physical characteristics of each carcass were carefully examined and measured. Relevant characteristics for this study include the percent of U.S. Select carcasses, the percent of yield grade 4 or 5 carcasses, the percent of light and heavy carcasses, and the average dressing percentage.

The weights of the serially slaughtered cattle do not correspond exactly with those used in the FCMS; however, the days on feed correspond closely to what is assumed in the FCMS. The four weight groups from the serial slaughter studies are thus assumed to correspond to 1,075, 1,125, 1,175, and 1,225 pounds. Figures on the relevant carcass characteristics for 1,100, 1,150, and 1,200-pound cattle are calculated by linear interpolation. Price discounts corresponding to the undesirable carcass characteristics are based on average market conditions. Price discounts and carcass characteristics used in this discounting regime are given in Table 5.

Table 5. Market-Based Fed Cattle Price Discounts and Serial Slaughter Carcass Characteristics Used in BEEFGAIN Simulation

Weight Group	% Select	% YG 4	%Light Carcasses[a]	%Heavy Carcasses[b]	Dressing Percentage
1,075	52.46	0.78	1.587	0.000	64.15
1,100	45.88	0.39	0.794	0.000	64.53
1,125	39.29	0.00	0.000	0.000	64.90
1,150	35.27	1.02	0.000	0.000	64.68
1,175	31.25	2.03	0.000	0.000	67.52
1,200	28.97	3.79	0.000	0.782	64.83
1,225	26.69	5.54	0.000	1.563	65.20
Discounts[c]	$7/cwt	$15/cwt	$25/cwt	$10/cwt	

[a] Light carcasses are those weighing less than 550 pounds.

[b] Heavy carcasses are those weighing over 950 pounds.

[c] Discounts are based on carcass price per hundredweight.

BEEFGAIN Results

Results of the BEEFGAIN simulation indicate that profits decrease substantially when cattle are over-finished. The amount of the decline in profits and the rate at which this decline occurs depend to a large degree upon the discounts for undesirable carcass characteristics. These discounts are variable and, like cattle and boxed beef prices, respond to conditions in the market. Figure 5 illustrates the relationship between profits and slaughter weights for both of the discounting regimes. In addition, this figure includes a profit curve from the FCMS. This curve represents one-half of the industry-level profits available under average cost of gain conditions (i.e., cost of gain equal to $0.46/lb.) in the FCMS. The level of this curve is determined by the feeder cattle and boxed beef prices used in calculating feedlot and packer break-even prices. Again, the level of this curve is not important for an examination of the relationship between profit and slaughter weight. Figure 6 illustrates how break-even fed cattle price and cattle weights change throughout the feeding period in the BEEFGAIN simulation.

The no-discount profit curve in Figure 5 illustrates how profits are affected by cost of gain changes as cattle weights increase. The effect of actual cost of gain changes is fairly minor over the range of weights from 1,100 to 1,175 pounds; however, the decrease in profits becomes relatively large at extreme weights.

The profit curve constructed using serial slaughter data and market discounts illustrates how feeding profits and slaughter weights are related in the actual fed cattle market. The addition of price discounts dramatically alters the consequences of under- or over-finishing cattle. In this illustration, maximum profit occurs at 1,150 pounds. Deviations from that weight result in very large reductions in profit. Of course, the rate at which profits decrease will depend upon the amount of the price discounts which, as noted earlier, depend upon market conditions. Still, price discounts will significantly reduce feeding profits for under- or over-finished cattle—compounding the negative impact on profits of cost of gain increases.

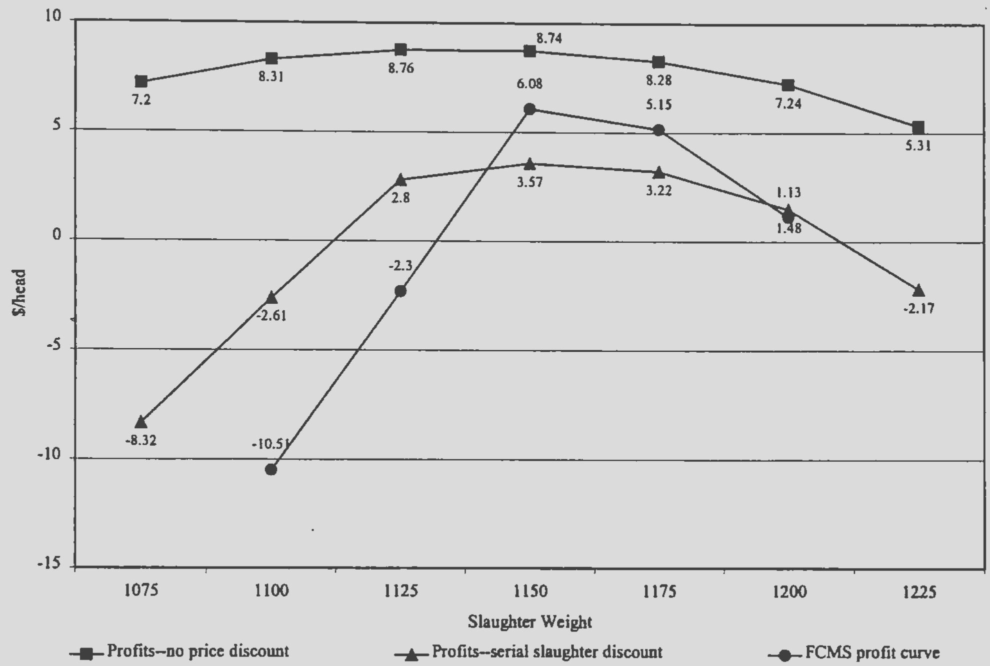
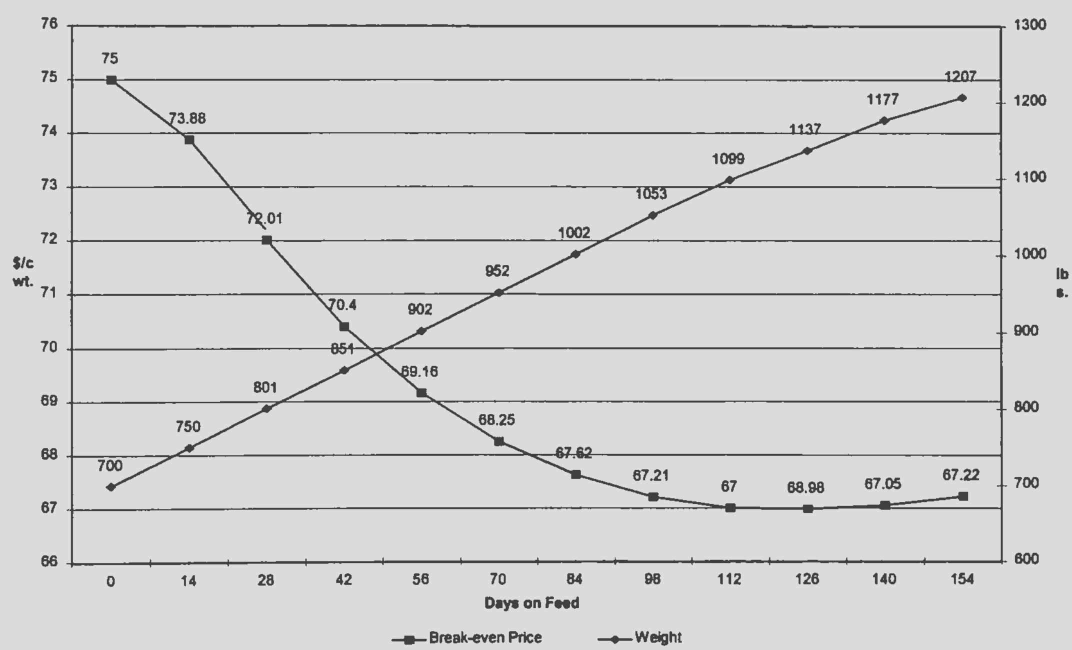


Figure 5. Comparison of the Effect of Slaughter Weight on Feeding Profits Using BEEFGAIN and FCMS



Note: Weight and break-even price figures are taken from BEEFGAIN simulation.

Figure 6. Fed Cattle Weight and Breakeven Prices Throughout the Feeding Period

The third curve in Figure 5 illustrates how profits in the FCMS are affected by slaughter weight. The basic shape of the curve corresponds very closely to that of the market-based curve; however, it is slightly compressed. That is, the decline in profits occurs over a narrower range of slaughter weights. The FCMS curve is also somewhat different in that a greater portion of the profit decrease is due to cost of gain effects than in the market-based curve. Nevertheless, a comparison of the two curves confirms that the FCMS is a good approximation of reality with respect to the issue of slaughter weight effects on feeding profits.

Industry Slaughter Capacity Utilization Rates and Volatility

Results from the Fed Cattle Market Simulator suggest that it is worth approximately \$3 per head to the packing plant industry to be able to stabilize slaughter volume at each plant's optimal volume. This \$3 figure is based on the fact that in the "No Coordination" simulation processing costs/head were \$68.18 versus \$65.06 in coordination strategy #1 where 40 pens of cattle per week were slaughtered when available. In addition to maintaining the optimal industry level of slaughter, strategy #1 also allocated the available pens optimally among the four slaughter plants.

The standard deviation of the weekly slaughter volume observed in the "No Coordination" simulation was approximately 6.4 pens. Given a mean of approximately 37.5 pens of cattle, this results in a coefficient of variation value of about .17. How do these values compare to actual industry values? To address this question data were obtained from the U.S. Department of Agriculture's Grain Inspection, Packers and Stockyards Administration (GIPSA). The data obtained were based on reported daily slaughter of fed cattle (including fed Holsteins) by all plants where fed cattle slaughter constituted 80 percent or more of total slaughter (35 plants) during the period from April 5, 1992, to April 3, 1993. Confidentiality prohibited GIPSA from providing any data that could be identified by individual plants. In addition, GIPSA did not have knowledge of the slaughter capacity rates of the plants in the data set. In order to estimate a plant's physical capacity it was requested that the average of the highest 15 slaughter days during the yearlong period be determined for each plant. This value was then used to form a daily slaughter capacity utilization index of the following form:

$$SCUINDEX_{tj} = (SLGVOL_{tj}/AVG15_j) \times 100$$

where,

$SCUINDEX_{tj}$ is the slaughter capacity utilization index for plant j on day t;
$SLGVOL_{tj}$ is the reported slaughter volume for plant j on day t; and
$AVG15_j$ is the average of the highest 15 days of slaughter volume for plant j.

To assure confidentiality, GIPSA did not provide the entire data set of 9,145 index values. Instead, they provided a table of summary statistics and a histogram of the slaughter capacity utilization index data. Table 6 reports the summary statistics provided. Two columns of values are reported. The first column provides summary statistics for the entire data set. The second column reports the same statistics but considers the data subset defined by observations with a capacity index number equal to or greater than .66. This data set will be referred to hereafter as the "truncated data" set because it was formed by removing/truncating the lower tail of the density distribution of the data in question. The data were divided in this manner in an attempt to separate days where a sharp drop in slaughter occurred due to factors other than volatility in cattle procurement. It is hypothesized that the days when a plant operated at less than 66 percent of its capacity (as determined by the average of its 15 highest slaughter days) were days when production was reduced due to mechanical problems, health inspection problems, storms, or any factor that caused the suspension of one or more shifts during the day (i.e., this would include Saturdays and holidays). It was felt that capacity utilization volatility due to such problems could not be eliminated by stabilizing cattle supplies with various vertical coordination strategies. Several points bear emphasis with regard to the data reported in Table 6. First, the data are skewed. Second, the median is above the mean and the third moment is significantly large and negative [which means the right side (tail) of the distribution curve declines more rapidly than the left].

Table 6. Statistical Summary of GIPSA Reported Plant Utilization Index Data

Data Item	All Observations	Observations With An SCUINDEX > .66
Number of Plants	35	35
Number of Observations	9,145	8,293
Number of Saturday Observations	450	256
Mean of SCUINDEX	84.92	88.09
Median of SCUINDEX	88.63	89.79
Variance of SCUINDEX	173.28	71.78
Third Moment of SCUINDEX	-3,436.81	-292.23
Fourth Moment of SCUINDEX	183,420.34	19,293.69

Figure 7 is a histogram of the data set. It illustrates the skew of the data set very well. It is of interest to note that there is a slight "bump" in the histogram bars at 47.5 percent. This bump is believed to reflect the frequency of single shift days. Most plants run two shifts per day but occasionally run one shift per day on a Saturday or on days set aside for extensive maintenance, etc. If this bump reflects days when plants were operating at their desired/optimal rate for one shift, then the implied two shift optimal/desired capacity utilization rates is 95 percent (i.e., 47.5 percent x 2). This leads to the second point. *The mean and mode of the data set are well below an index value of 100, thus indicating that plants were generally not operating close to their demonstrated physical limit during the data period.* One reason plants may not have been utilizing their full physical capacity was that the data period used (i.e., April 1992 through March 1993) was near the bottom of the cattle cycle, thus making the procurement of an adequate/optimal number of cattle more difficult. Also, it is also possible that it is not economically optimal to sustain a plant's operation for a long period of time near its physical maximum rate. Finally, it should be noted that the coefficient of variation for all observations is .155 and the coefficient of variation for the truncated data set is .096. Recall that the coefficient of variation for slaughter in the "No Coordination" simulation was approximately 0.17. Thus the total data set has a coefficient of variation similar to the "No Coordination" simulation generated data, but the truncated data set which was created to try to focus on volatility due to slaughter procurement/coordination issues has a significantly lower coefficient of variation.

The cost to the industry implied by the volatility in slaughter rates described by the GIPSA data was estimated using stochastic simulation. An empirical distribution based on the GIPSA histogram data was used to generate random slaughter capacity utilization rates. A total of 1,000 random plant capacity utilization rates were simulated from the empirical distribution for each simulation done. The slaughter cost associated with each random capacity utilization rate was evaluated using the cost curve figures in Table 7. The cost curve values reported in Table 7 were derived from work done by Duewer and Nelson and is believed to be the most representative available figures for the industry. The cost curve reported in Table 7 is very similar to the cost curve used in the simulator with one exception. The cost curve reported in Table 7 has been adjusted upward to reflect the fact that typical current processing cost levels for killing and fabricating an animal are about $85-90/head instead of the $68-76/head assumed in the simulation model. Linear interpolation was used to evaluate costs for random capacity figures between those reported in the table.

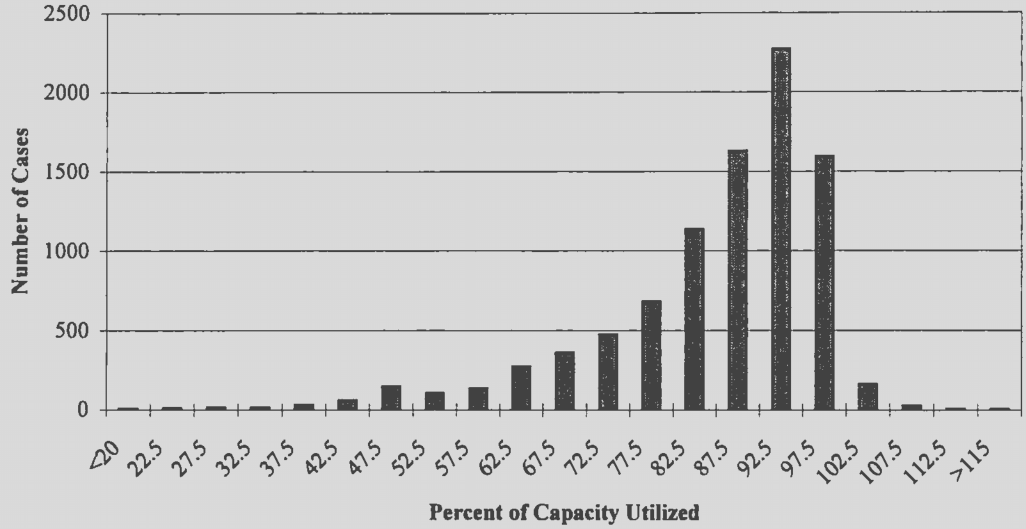


Figure 7. Distribution of Daily Slaughter Rates as a Percent of Physical Plant Capacity

Table 7. Combined Killing and Fabrication Costs/Head for Alternative Slaughter Rates

Slaughter Rate as a Percent of Physical Plant Capacity	Killing and Fabrication Costs/Head
40	$169.69
50	$138.13
60	$117.81
70	$105.79
80	$ 96.61
90	$ 89.59
100	$ 87.50
110	$ 87.61
120	$ 87.74

The mean of the 1,000 cost figures simulated using the entire data set was $94.09. Comparing this cost level to the least-cost processing cost specified, which was $87.50/head for operation of a plant at 100 percent of capacity, yields a difference of $6.59 (i.e., $94.09-$87.50). *This $6.59 per-head difference is deduced to be the typical cost inefficiency experienced by slaughter plants during the data period covered by the GIPSA data set.* Upon further reflection, this inefficiency amount can be separated into two parts. Those parts are: a) the cost of operating at an average capacity below the optimal capacity; and b) the cost of volatility around that average level. The simulated mean slaughter capacity utilization rate was 85.1 percent, which is very close to the reported 84.92 percent . The processing cost reported in Table 7 that is associated with a capacity utilization rate of 85.1 percent is $93.06. This value is derived by linear interpolation between the values of $96.61 and $89.59 which are respectively the cost figures for 80 percent and 90 percent capacity utilization. The difference between $93.06 and $87.50 (the least cost-value associated with 100 percent capacity utilization) is $5.56. *Thus it is deduced that the majority of the total $6.59 cost inefficiency is due to the average plant utilization rate being about 15 percent below the assumed least-cost utilization rate of 100.* This leaves $1.03 of cost inefficiency ($6.59 - $5.56) being attributed to instability/variance around the mean capacity utilization rate.

The $1.03 of inefficiency attributed to non-constant slaughter utilization rates can intuitively be explained as arising from two factors: a) the cost curve increases more rapidly below the capacity of 85 percent than it decreases above that capacity; and b) the distribution from which the random capacity utilization rates were drawn is skewed. The first condition causes random deviations that fall below the mean capacity utilization rate to be penalized by added costs more than random deviations that fall above the mean are rewarded with reduced costs. The effect of the skew in the data is mixed. The fact that the median is above the average implies that slightly more observations will be randomly drawn above the mean than below, thus causing more decreases in cost relative to the cost at the mean than increases. However, the shape of the skew also implies that observations drawn below the mean will typically have larger deviations from the mean and thus draw bigger cost penalties compared to the cost reductions given to typically smaller deviations from the mean for random observations above the mean. Another way of stating the causes of increased cost due to instability around a given mean capacity utilization level is to state that "if the cost curve were linear and if the random distribution were normally distributed, then the cost of instability would be zero."

The above slaughter plant inefficiency cost estimates are based upon the entire GIPSA data set. It was previously argued that days with plant utilization rates which are below 66 percent of the plant's estimated physical capacity are likely days where the low capacity utilization rate is due to factors other than the inability to procure the desired number of cattle. If the histogram reported in Figure 7 is truncated at a capacity utilization level of .66 and a new empirical distribution function formed from the data above the .66 cut-off point, the inefficiency estimates obtained are as follows: total inefficiency--$4.17; inefficiency due to low volume--$3.14; and inefficiency due to instability--$1.03. The reduction found in total inefficiency and inefficiency due to low volume is as expected, but surprisingly the inefficiency due to instability is unchanged between the simulation based on the total data set versus the simulation based on the truncated data set. A decline in total inefficiency cost could be expected because the mean of the truncated data set is higher than the mean of the total data set and the variance of the truncated data set is lower than the variance to the total data set. The failure of the cost of inefficiency due to instability to drop in this case is not in error, but is (as we will see presently) misleading and due to a unique trade-off occurring between competing factors that control the magnitude of cost due to instability. An explanation of this phenomenon will be provided presently.

The assumption that a plant's optimal capacity is equal to the average of its 15 largest slaughter days, while logical, is arbitrary. A sensitivity test can be conducted to determine the effect of this assumption on the cost inefficiency estimates made. Specifically the question to be answered by this test is "What is the implication for the inefficiency cost estimates made if it is assumed the lowest cost point of operation is at a volume which is 95 percent, 90 percent, etc. of the average found for the 15 highest volume slaughter days?" It can be demonstrated that this sensitivity test is essentially the same as a sensitivity test to answer the question of "What is the implication for the inefficiency cost estimates made if it is assumed the packing plant could purchase a larger number of cattle and raise its average capacity utilization rate to perhaps 90 or 95 percent?" Separate simulations can be conducted which show that shifting the low point of the cost curve down 5 index points has the same effect on estimated inefficiency costs as shifting the distribution of slaughter capacity utilization rates up 5 index points. What is critical in this analysis (and in reality) is the difference between the simulated (actual) random slaughter capacity rates and the assumed low cost slaughter capacity utilization rate.

This analysis cannot be certain that the mismatch between the assumed optimal slaughter rate and the actual industry slaughter capacity utilization rate (as calculated from the GIPSA data) is due to a) low supplies of cattle during the data period; b) an overestimate of the plant's optimal slaughter rate; or c) some combination of both of these factors. To conduct a sensitivity test of this question, the assumed low cost volume index was adjusted in increments of 5 points between 75 and 105. Using the two GIPSA data sets previously described, this results in ratios between the assumed optimal capacity utilization rate and the mean of the simulated capacity utilization rate that range from about .8 to 1.15. The results of these sensitivity tests for the two GIPSA data sets are reported in Table 8.

The estimated inefficiency costs discussed above, i.e., the estimated costs when the optimal slaughter capacity utilization rate index value is assumed to be 100, are presented in the second lines of Part A and Part B of Table 8. The other lines report the result of alternative assumptions about the optimal/low cost slaughter capacity utilization rate. Part A of the table presents results when the stochastic simulation is based on the entire data set, versus Part B, which reports results based on use of the truncated data set.

Two patterns in the values comprising Table 8 provide insight into the nature of the cost inefficiency caused by low and volatile slaughter capacity utilization rates. First, the inefficiency cost from non-optimal average slaughter capacity utilization rate approaches zero as the assumed "Optimal Slaughter Capacity Utilization Rate" (column #2) approaches the actual average slaughter capacity utilization rate of the two data sets defined here, which in turn results in the ratio reported in column #1 approaching 1.00. It should also be noted that cases for which the actual average slaughter capacity utilization level is below the assumed Optimal Slaughter Capacity Utilization level have higher associated costs than those where the actual average capacity utilization rate exceeded the assumed Optimal Slaughter Capacity Utilization Rate. This is the case because the cost curve remains relatively flat beyond its low cost volume. The second general observation is that the cost inefficiencies generated from unstable slaughter levels appear to peak when plants are operating at a little less than 90 percent of the specified Optimal Slaughter Capacity Utilization Rate. This follows from the fact that with a given random distribution of slaughter capacity utilization levels, the greatest cost of instability occurs at a point on the cost curve where the second derivative of the cost curve is the largest, i.e., where the curve is changing slope the fastest. In the case of the cost curve developed here, this occurs at approximately 90 percent of full utilization (see Figure 8). As explained above, with extreme curvature of the cost curve, random low values drawn from the slaughter utilization rate distribution are penalized more than random high values are rewarded. One might at first think that the largest cost of instability would occur when the average slaughter level was equal to the capacity utilization rate at the low point on the cost curve. This would be one's intuition because deviations in either direction, from the low point, would result in higher costs. However, the cost curve derived from Duewer and Nelson's work is very flat beyond its low point and, to some degree, is also relatively flat just before its low point. Hence, the majority of the deviations that occur in this area do not affect cost by a magnitude which would result in large changes in cost. This is especially the case with positive deviations above the low cost capacity utilization level.

Table 8. Simulated Cost Inefficiencies from Non-Optimal Average Daily Slaughter Rates and Variable Daily Slaughter Rates

Part A. Results Using the Total Data Set
(Mean Slaughter Capacity Utilization Index = 84.92)

Ratio of Actual vs. Optimal Capacity Utilization Rate (1)	Optimal Capacity Utilization Rate (2)	Total Cost Inefficiency (3)	Inefficiency From Instability (4)	Inefficiency From Non-optimal Utilization Rates (5)	Simulated Mean (6)
0.81	105	$10.24	$0.80	$9.44	84.6
0.85	100	$ 6.59	$1.03	$5.56	85.1
0.89	95	$ 4.26	$2.10	$2.16	85.0
0.94	90	$ 2.84	$1.73	$1.11	84.7
1.00	85	$ 1.70	$1.65	$0.05	85.3
1.06	80	$ 1.14	$1.08	$0.06	85.0
1.13	75	$ 0.84	$0.73	$0.11	84.6
Avg.0.93	92.5	$ 4.46	$1.40	$3.06	84.9

Part B. Results Using Index Values Greater Than .66
(Mean Slaughter Capacity Utilization Index = 88.09)

Ratio of Actual vs. Optimal Capacity Utilization Rate (1)	Optimal Capacity Utilization Rate (2)	Total Cost Inefficiency (3)	Inefficiency From Instability (4)	Inefficiency From Non-optimal Utilization Rates (5)	Simulated Mean (6)
0.84	105	$6.73	$0.31	$6.42	88.8
0.88	100	$4.17	$1.03	$3.14	88.5
0.93	95	$2.19	$0.87	$1.32	88.7
0.98	90	$1.09	$0.77	$0.32	88.5
1.04	85	$0.50	$0.46	$0.04	88.7
1.10	80	$0.26	$0.16	$0.10	88.5
1.17	75	$0.20	$0.04	$0.16	88.7
Avg.0.96	92.5	$2.49	$0.60	$1.89	88.6

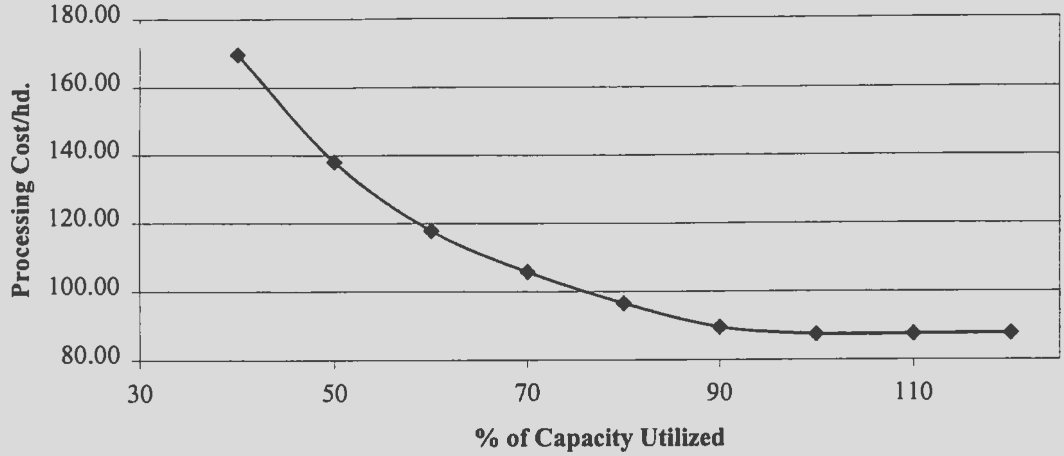


Figure 8. Combined Kill and Fabrication Cost/Head by Rate of Capacity Utilization

The trade-off that caused the phenomenon of no change in the cost of instability estimates between the two GIPSA data sets contrasted earlier can now be resolved. The total GIPSA data set has a lower mean slaughter level but a higher variance than the data subset created by removing all observed index values below .66. Reducing the variance by truncating the total GIPSA data set in this manner should reduce the simulated/estimated cost of instability. But raising the average slaughter level into the heart of the most non-linear segment of the cost curve increases the cost of instability. By chance these two offsetting forces balanced exactly between the two data sets in question when the optimal capacity utilization rate was assumed to be an index of 100.

The question that arises now is, of all the values presented in Table 8, which is the most accurate estimate of actual industry costs to packing plants due to non-optimal and unstable slaughter volumes? The answer is the typical economist answer of "it depends" and it probably varies over time. The period over which the GIPSA data were collected was one in which the slaughter level was about 1 percent above the previous cyclical low in slaughter numbers and about 12 percent below the previous cyclical high in slaughter numbers. Considering this fact, and assuming the industry's aggregate slaughter capacity does not change over a cattle cycle, it can be inferred that over the course of the cattle cycle, slaughter plants would typically operate 5 percentage points closer to their physical capacity limit than they did during the data period in question. Given that the average capacity utilization rate in the GIPSA data was a little less than 85 percent, this would imply an average capacity utilization rate over an entire cycle of about 90 percent. Assuming the difference between the mean utilization rate in the total data set and truncated data set would remain at about 3 percent (irrespective of any change in the average capacity utilization rate) leads to the conclusion that the mean capacity utilization rate of the truncated data set would average about 93 percent over one complete cattle cycle. Given these assumptions, and the assumption that the least-cost level of operation is at a plant's physical maximum rate, row three of Part B of Table 8 appears to be uniquely relevant. It is for a plant operating at 93 percent of its optimal capacity. *The indicated total inefficiency cost is $2.19/head with $.87 of that cost due to slaughter volatility and $1.32 due to a less-than-optimal volume. This would appear to be the most representative estimate of the long-term cost to the industry of non-optimal and volatile daily slaughter rates.* It is important, however, to recognize that total cost inefficiency likely changes dramatically over the cattle cycle. During low points in the cattle numbers cycle, the plant utilization rate associated with the mean of the truncated data set could drop to around 87 percent. This would cause the inefficiency cost to rise to almost $5/head. During the peak of the cattle numbers cycle, the plant utilization rate associated with the truncated data set mean could rise to about 99 percent, thus causing the inefficiency cost to drop to less than $1/head.

A potential compounding effect on the magnitude of the change in cost inefficiency hypothesized for slaughter plants over a cattle cycle is the expectation that when cattle numbers are large, cattle slaughter rates will not only be nearer to optimal plant capacities, but also will probably be more stable. The critical implication that follows is that one of the reasons that packing plants will be more aggressive bidders for both cash cattle and contracted cattle when cattle supplies are short is to avoid processing cost inefficiencies from less-than-optimal volumes and from unstable volumes.

In closing this section of this paper, it should be noted that the average optimal capacity utilization rates and slaughter volume instability occurring in the FCMS are similar to those revealed by the GIPSA data. In the "No-Coordination" simulation conducted with the FCMS, the average slaughter rate was 37.5 pens per week, which is approximately 94 percent of the optimal aggregate slaughter capacity specified in the simulator. The coefficient of variation for slaughter was .17. Since the simulator eliminates all causes of slaughter flow disruption except market coordination, it is probably the most appropriate to compare the simulated values to the values derived with the truncated GIPSA data set. For this data set, plants were calculated to have an average capacity utilization rate of 88.1 percent with a coefficient of variation of .096. Thus, the truncated GIPSA data set shows poorer utilization rates but more stability in slaughter flows than the simulated data. Despite these differences in slaughter levels and instability, the cost analysis done with the truncated GIPSA data and the experiment done with the simulator yield similar estimates for the cost to packing plants of non-optimal and unstable slaughter rates. The estimated cost from the simulator was approximately $3/head while the estimated cost from the truncated GIPSA data was a little above $4/head for conditions that existed during the data sample period. However, it was speculated that the GIPSA data may have come from a period when slaughter levels could be expected to be low relative to the industry capacity available (i.e., the period was just past a low in cyclical cattle numbers). Therefore, the estimated average cost of non-optimal slaughter levels over an entire cycle was deduced to be about $2/head. Approximately 40 percent of this $2 cost was estimated to be due to volatile capacity utilization rates (cattle procurements), leaving 60 percent attributed to a less-than-optimal average capacity utilization rate (i.e., excess plant capacity relative to cattle supplies).

Summary and Conclusions

Experimental simulation was used to determine the effects of non-price coordination on industry-level profits and inefficiency costs in the fed cattle market. *Results indicate that large gains in industry-level profit can be made using relatively simple non-price coordination strategies*. All but one of the non-price coordination strategies increased industry profits substantially. This increase in profits was due both to cost reductions and to boxed beef price increases.

Simulation results also give some insight into why non-price coordination has not been widely adopted in the cattle market. In this study, packers and feeders would favor vastly different strategies. Packers would favor the study's strategy 1—always slaughter 40 pens—because this strategy resulted in the lowest processing costs. Total industry losses incurred under this strategy were due to higher cost of gain associated with increased cattle weights and higher price discounts. Assuming that packers could and would pass these high price discounts back to feeders in the form of lower bids for fed cattle, packers could avoid almost all of the increased costs associated with this strategy. At the same time, they would benefit from being able to sell a much greater volume of boxed beef. Feeders, on the other hand, would clearly favor the study's strategy 3—sell one-third of the 1,125-pound cattle each week, and sell the remaining two-thirds of the group the following week at 1,150 pounds. This strategy resulted in the lowest cost of gain by avoiding the feeding inefficiencies which result from over-finishing cattle. Not surprisingly, neither of these strategies was optimal in terms of maximizing industry-level profits, though strategy 3 was much closer to optimal than strategy 1.

These results of the analysis confirm the conventional wisdom in the feeding industry that feedlots need to keep their marketings current, that is, to avoid holding cattle in feedlots to heavy weights. Furthermore, this analysis illustrates why feedlot managers sometimes find it hard to keep marketings current, that is, packers have an incentive to keep showlists full to make it much easier for them to maintain a consistent, efficient flow of cattle through their plants. In reality—as in the simulations studied—packers benefit from marketing strategies which result in high volumes of heavy cattle while feedlots benefit from strategies which result in relatively low volumes of light cattle.

To summarize, simulation employed in the research indicates that substantial gains in industry profit could result from the use of non-price coordination in the fed cattle market. Achieving these higher profits would require an unprecedented degree of cooperation between feeders and packers. The reason for this is that coordination strategies, which raise industry-level profits, are not optimal for packers from a cost minimizing perspective. Because gains in industry-level profits far exceed the increase in processing costs, it is possible that a redistribution of profits could be achieved which would adequately compensate packers for their higher costs. Due to the market power of packers, it seems likely that they would, in fact, receive the lion's share of any profit increases. A more thorough examination of how profits are divided in the FCMS is needed, but that issue was beyond the scope of this study.

Data and information were collected to conduct two additional simulations independent of the FCMS. These simulations were conducted primarily to determine how different the results of the FCMS might be from reality given the simplifications present in the FCMS. The first simulation focused on the realism/accuracy of the simulated effect of changes in slaughter weight on cattle feeding profits. Results obtained from Oklahoma State's BEEFGAIN feedlot growth simulator indicate that feedlots lose up to about $10/head of their potential profits when cattle are either under- or over-finished. The amount of lost profits and the rate at which profits decline in response to the degree of under- or over-finishing depend upon the market-determined carcass discounts and changes in feed conversion efficiency. Simulations with the BEEFGAIN simulator indicate that the relationship between feeding profits and slaughter weight follows the same basic pattern in the BEEFGAIN simulator and the FCMS, i.e., they peak at about the same weight and begin and end at similar levels. However, penalties for under- or over-finishing cattle in the FCMS are incurred over a narrower weight range than generally occurs in reality. This departure from reality was intentional in the FCMS to encourage (in fact, to force) participants to market their cattle within a time frame that would facilitate as many simulation periods as possible during a given workshop so participants could experience as many marketing decisions as practically possible.

A stochastic simulation designed to measure the effect of fed cattle supply variability on packer profits was also performed to analyze the realism of the slaughter volatility and associated costs generated by the FCMS. This simulation was performed by using an empirical distribution of plant capacity utilization data that was derived from data obtained from the USDA's Grain Inspection, Packers and Stockyards Administration (GIPSA). Results indicate that in the long-run (i.e., over an entire cattle cycle) packers probably lose just over $2/head to cattle supply variability and capacity under-utilization. This figure likely varies a great deal over the course of a cattle cycle, i.e., from approximately $5/head when cattle numbers are near their cyclical low, to only $1/head when cattle numbers are near their cyclical high. The FCMS generates an average cost of supply variability and capacity under-utilization of about $3/head. Much of this higher cost was due to the fact that slaughter volatility was about twice as high in the FCMS than was estimated to exist in reality. This is likely largely due to the "thinness" of the FCMS market, i.e., only about 40 units/pens of cattle are traded each trading period. Thus a one-pen variation causes a 2.5 percent change in volume.

The results of the research indicate significant incentives to stabilize flows of cattle through slaughter/fabricating facilities. Added costs of up to $5 per head (up to a range of $150 to $200 million per year) are incurred with the level of slaughter variation present in the industry. This reality prompts non-price means of coordination in the form of contracts, business arrangements, etc., between packers and cattle feeders. How the savings associated with reducing costs, by decreasing variability in slaughter levels via forward contracts and other means of coordination, would be shared was beyond the scope of this study. But the benefits will, of course, be distributed across cattle feeders, producers, and packers.

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