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**Analysis of the Physical and Market Factors Influencing  
the Relationship between Slaughter Cattle Weight and  
Price: An Application of Experimental Economics**

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James Trapp, Stephen Koontz, Derrell Peel,  
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# ANALYSIS OF THE PHYSICAL AND MARKET FACTORS INFLUENCING THE RELATIONSHIP BETWEEN SLAUGHTER CATTLE WEIGHT AND PRICE: AN APPLICATION OF EXPERIMENTAL ECONOMICS

James Trapp, Stephen Koontz, Derrell Peel, and Clement Ward\*

The relationship between slaughter cattle weight and price is generally understood in the cattle industry but has not been rigorously studied. The primary reason this relationship has not been studied is a lack of detailed data regarding slaughter weight and associated prices received. Spot market price data for beef slaughter cattle are reported in terms of the average price received over at least a 100 pound weight range. Monthly average prices and average slaughter weights are reported, but this type of time series data does not provide the proper basis to examine the critical question producers have regarding the slaughter weight/price relationship. That question is, "What can be expected to happen to price as slaughter cattle are held to heavier and heavier weights?" To answer this question both cross section and time series data are needed on individual pens of cattle sold at various weights. A precise answer to this question and an understanding of what causes price received to change with slaughter weight is critical to short-run fed cattle marketing decisions.

## Methodological Approaches

Two different approaches will be used to determine and analyze the relationship between slaughter weight and price. The first approach will use a set of pen level closeout summaries available from approximately eighty-five feedlots from 1986 to 1993. The second approach will use data generated by an experimental economics model of the fed beef market called the "Fed Cattle Market Simulator". The main purpose of using the experimental market model is to glean an enhanced understanding of the reasons behind any relationship existing between slaughter weight and slaughter price.

Conventional wisdom of producers in the industry is that slaughter cattle price relative to slaughter weight reaches a maximum at a weight of about 1150 to 1200 pounds. This maximum is believed to exist because the quality of animals begins to decline after this weight due to excess fat. In fact price is expected to drop rather rapidly at this point. However, conventional wisdom also holds that price is affected very little by weight over perhaps a 150 to 250 pound weight range. This range provides feeders with a "window of time" in which to market cattle. Cattle within this window are generally referred to as being "on the show list" or in other words available to be shown for sale.

The hypothesis to be tested in this study through the use of experimental economics is that the price relationship that exists between slaughter weight and price is influenced as much, if not more, by changes in bargaining power that occur with changes in slaughter weight, versus changes in meat quality that are associated with changes in slaughter weight. It is hypothesized that most cattle are sold before they reach weights where their quality begins to decline. However it is hypothesized that the price received for these cattle at the upper end of the show list weight range begins to decline as their weight increases in spite of their continued high quality. This is hypothesized to be the case because of a loss of market bargaining power by sellers as cattle increase in weight.

\* Regent Professor, Assistant Professor, Assistant Professor, and Professor of Agricultural Economics at Oklahoma State University.

### Results Obtained From Closeout Data

A data set consisting of the closeout data for all pens of cattle sold by approximately 85 feedlots collectively feeding about 25 percent of the cattle in the nation was used to estimate the relationship between slaughter weight and slaughter price. Data were available from January 1986 to April 1992. Approximately 33,000 observations are in the data set for pens of slaughter steers and heifers.

A quadratic relationship was estimated between slaughter steer weight and price. The relationship found is depicted in Figure 1. The relationship is as expected. Slaughter price reaches a maximum at about 1,075 pounds. However, the slaughter price received does not vary by more than approximately \$.75/cwt. over a weight range from 900 to approximately 1,225 pounds. Thereafter slaughter prices decline sharply. The shape of the curve is consistent with the concept of a show list existing from approximately 1,000 pounds to 1,175 pounds.

The parameters for both the weight and weight squared terms were highly significant indicating that slaughter price does change with weight and that a maximum value does exist. Various measures were used in the estimation process to remove the influence of factors other than weight upon slaughter price. Changes in price over time were neutralized by including the nearby futures price. Likewise differences in animal quality were dealt with by use of an animal quality index. Dummy variables were used to separate steer and heifer data. Details of the estimation process are available in Koontz and Trapp. The main point to be established here is that a nonlinear relationship exists between slaughter price and weight and that a maximum price can be expected to be received somewhere near the middle of the normal marketing weight range.

### The Experimental Economics Model

To analyze why slaughter prices peak within the marketing weight range observed in the closeout data set, an experimental economics model was used. The design and operation of this model will first be examined in this section. Following this examination results will be present from analyses using data generated from the experimental model to test the hypothesis that bargaining power has a significant influence upon the slaughter price/weight relationship. The interested reader is referred to Koontz et al. for a more detailed discussion of the experimental model's structure. What follows is a brief overview of the model which focuses upon the cost structure of the model.

#### The Fed Cattle Market Simulator

The experimental economics model used is commonly referred to by its participants as the "Packer-Feeder Game". It simulates the market dynamics and competition between eight feedlots and four packing plants. Each firm is managed by a team of three individuals. Feedlots are given a set of cards, with each card representing a pen of 100 head of cattle. Each card indicates the purchase date, purchase price and feedlot receiving the animal. All feeder animals are assumed to enter the feedlot at a weight of 700 pounds and grow twenty-five pounds per week (i.e. each simulation round/trading period). Feedlots are given additional pens of 700 pound animals each week. After sixteen weeks of growth these animals are available for sale. The game/experiment focuses upon a five week period when animals are deemed to be within the "marketing window" or "on the showlist". This period is defined as the time animals are between 1,100 pounds and 1,200 pounds. Profits of both the feedlots and packing plants depend upon the number and weights of animals traded each period, firm production cost schedules, the price at which the cattle are traded, and exogenous market conditions. The experiment

scenario varies the supply of cattle being processed through the system by controlling the rate at which pens of 700 pound cattle are placed into the system. For this study 48 weeks of trading were simulated. During this time placements were varied by about 25 percent to create periods of abundant and sparse supplies of cattle.

Each packing plant has a unique capacity level and a u-shaped short-run average cost curve. The price that a packing plant will receive for its processed meat depends upon exogenous market conditions for processed meat (boxed beef), the volume of meat processed by all four packing plants, and the weight of animals purchased. Packers and feedlots negotiate sales volume and prices face to face. Transactions are recorded on the card representing each pen of cattle. Each transaction is processed through an electronic scanner as the transactions occur. Data generated from the scanner are immediately processed by the computer and used to up-date an electronic light board that reports the market's volume and high/low price range for the current trading period. The transactions data is also fed into a computer model of the beef market which generates realistic boxed beef market price responses to changes in the volume of processed meat resulting from participant transactions. The boxed beef price equation is a lagged adjustment model estimated from historical data. Details of this model are presented in Meyer's M.S. thesis and in Koontz, Trapp and Meyer.

Computer software has been designed to generate standard financial statements (balance sheets, cash flow statements and inventory reports) for each feedlot and packing plant based upon the information on the transaction forms entered into the electronic scanner. These statements are distributed to each team after each trading period. A trading period lasts approximately six-to-eight minutes and simulates one week of real time. In addition to individual firm financial data the computer software is also designed to issue "cattle on feed reports" every four weeks. This report follows the same format as the USDA quarterly cattle on feed report.

### *The Feedlot Environment*

The cattle feeding cost structure faced by feedlots is summarized by the break-even analysis table presented below for a pen of 1,150 pound cattle.

<u>Table 1. Feedlot Break-Even Analysis For a Pen of 1,150 Pound Cattle</u>	
Purchase Cost (700 lbs. x \$97.74/cwt.)	= \$684.18
Feeding Cost (1150 lbs. - 700 lbs.) x \$0.477/lb)	= \$214.65
Total Cost	\$898.83
<u>Break-Even Price (Total Cost/11.5)</u>	<u>= \$ 78.16</u>

The above calculations are relatively simple and ignore interest cost and death loss. However, they capture the changing cost of feeder animals and cost of gain which are the main factors influencing the break-even price. Calculation of the break-even price for 1,100 and 1,125 pound cattle follow the same procedure as that shown for 1,150 pound cattle, except the number of pounds gained is adjusted for the different slaughter weight. A modification is made to the break-even calculations process for 1,175 and 1,200 cattle. This modification is intended to reflect the rising cost of gain as cattle reach their mature weight. Specifically, the cost of gain per pound is increased by 8 percent for 1,175 pound cattle and by 18 percent for 1,200 pound cattle. This is a somewhat sharper rise in cost of gain per pound than likely exists in reality. But the weight range and time period that cattle are allowed to remain on the show list is shorter in the experimental model than in reality. Thus, when combined these two modifications are deemed to generate a time compressed equivalent of the change in cost of gain over the actual showlist weight range. Compressing the showlist time period to five weeks helps to accelerate the experiment.



Information is available to the feedlot teams to calculate their break-even price for every pen of cattle and for each possible weight it could be sold at. However, due to the pace of the game/experiment, the teams are not able to calculate all break-even prices for all sales options used. Thus "guess-timates" are made of current break-even prices based on profits and losses of previous sales of cattle and even estimates for similar weights of cattle. This type of "guess-timating" is not deemed to be far from what happens in reality in many cases.

### *Packing Plant Environment*

The cost structure faced by the packing plant is somewhat more complex than that faced by the feedlot. Table 2 below presents a set of cattle characteristics that are used in a break-even or bid price calculation for packers. This table, together with a set of discounts applied for inferior characteristics can be used to determine an "adjusted boxed beef" price for each weight of cattle given the base boxed beef price for choice, yield grade 3 carcasses. The discounts used in the experiment are as follows: Select carcasses - \$5.00/cwt.; Yield Grade 4-5 - \$10.00/cwt.; Light carcasses - \$2.00/cwt.; Heavy Carcasses - \$2.00/cwt. The adjusted boxed beef price can then be used in conjunction with the dressing percentage and carcass weight to determine the total carcass value. The next step in the process of determining a packer break-even price is to subtract the processing cost/head from the carcass value and add in the byproduct value. A byproduct value of \$8.50 per cwt. of live weight is assumed.

Table 2. Slaughter Cattle Characteristics by Weight

Live Weight	Carcass Weight	Dressing Percent	% Choice	% Select	% YG 1-3	% YG 4-5	%light Carcasses	%heavy Carcasses
1100	682	62.0	59	41	98.5	1.5	10	0
1125	703	62.5	63	37	97.0	3.0	5	0
1150	724	63.0	67	33	95.5	4.5	0	0
1175	746	63.5	71	29	93.5	6.5	0	5
1200	768	64.0	75	25	91.0	9.0	0	10

Determination of an appropriate processing cost adds another complication to the packer break-even price calculation. U-shaped short-run average cost curves are included in the experimental model for each packer, thus each packing plant's processing cost is a function of the volume of cattle they process. Each of the four packing plants is assumed to have a different optimal capacity. There are two relatively large firms in the experiment and two relatively small firms. The specific shape of the cost curve for each firm was determined from research by Duewer and Nelson. Figure 2 depicts the basic shape and relationship of the individual firm short-run average cost curves used in the experimental model and the associated industry long-run average cost curve each short-run curve was derived from.

A final point to note with regard to the environment faced by the meat packer is that packers do not know what boxed beef price they will receive for the meat produced from cattle purchases. Cattle that are purchased in the current week are sold in the boxed beef market the following week. The price received for boxed beef depends upon the current volume of marketings and marketings over the past nine weeks. The weekly price dependent boxed beef demand function estimated by Meyer is used in the experimental model to simulate boxed beef price response to experimentally generated sequences of slaughter.

### *The Experimental Packer-Feeder Market Environment*

The above described cost structures for feedlots and packing plants, while simplified, serve to represent the basic cost structure of the fed beef market. All modifications made were made explicitly to make decision making by experiment participants focus upon the bargaining and marketing process and to allow them to do so within a reasonable amount of time. A careful balance between realism and functionality in an experimental setting was the overriding consideration guiding the design of the cost structures described in the preceding section.

When the feedlot and packing plant processing cost structures described above are viewed jointly, their typical relationship is that depicted in Figure 3. The curve for packer break-even prices rises steadily over the showlist weight range from 1,100 pounds to 1,200 pounds. In actuality the adjusted boxed beef price begins to fall above 1,150 pounds. However, since the processing cost remains constant for all weights of cattle the break-even bid price continues to rise as slaughter weight increases. Personal communication with meat packing industry managers has verified the basic shape of the packer break-even price curve depicted in Figure 3.

The feedlot break-even price pattern by weight is shaped quite differently from the packer break-even price pattern. Feedlot break-even prices fall until a weight of 1,150 pounds. This is due to the fact that the costs of gain used in the experimental market vary between \$.45 and \$.50 per pound. Thus, given a purchase price of feeder cattle between \$80 to \$105/cwt. the break-even price of slaughter cattle falls as additional weight is gained. However the penalties imposed on cost of gain at 1,175, 1,200 and 1,225 pounds of 8, 18 and 30 percent respectively, cause the feedlot break-even price to begin to rise past 1,150 pounds. As previously noted this increase in cost of gain may compress the real cost of gain increase that occurs over a 100 to 150 pound weight range into a fifty pound weight range, but is deemed representative of actual rises in the cost of feeding cattle as they approach mature weights.

Before concluding this discussion of the experimental model's cost structures and market environment one more key point must be made. Figure 3 does not depict what happens to packer break-even prices at 1,225 pounds. This is because traditional packers are assumed to not purchase 1,225 cattle. Such cattle are deemed to be "too big to fit in a box", or in other words they do not meet the boxed beef specifications of major packers. Therefore, they must be sold to specialty packers at a considerable discount. Thus within the rules of the experimental simulation, participant packers are not allowed to purchase 1,225 pound cattle. Instead they are purchased by the experiment management at a discount ranging from \$2/cwt. to \$10/cwt. below the previous trading period's average price for 1,150 cattle. The actual discount depends upon the volume of 1,225 pound cattle sold, i.e. the greater the volume the greater the discount. Thus there is a strong incentive on the part of feedlots to sell cattle before they reach 1,225 pounds. Again this is deemed to be realistic of the market for slaughter cattle.

The key experimental property to note with regard to Figure 3 is that a curve passing through the midpoints between the packer break-even bid price and the feedlot break-even sales price, has a positive slope that increases in steepness as weight increases. This curve will be referred to here as the "50-50 bargaining power" curve or "equal profit" curve. It represents the price that would be settled upon by packers and feeders if they had perfect knowledge of each others cost structures and equal bargaining power. Two key points should be made with regard to this curve. First, it clearly shows that all cattle should be sold at 1,150 pounds because this is where the greatest amount of profit can be shared. Secondly its curvature is distinctly different than that of the weight/price curve depicted in Figure 1 which was estimated from actual closeout data. Thus if the assumptions used to construct the cost environment for the experimental model are correct, it would appear that implied economic value of beef animals by weight (as depicted by the 50-50 bargaining power curve in Figure 3) is different from the

real prices received (as depicted by the estimated actual weight/price curve in Figure 1). Which is right, the estimated real weight/price curve, or the assumed 50-50 bargaining power curve? Results presented presently from the experimental simulations suggest both may be right and that systematic imbalances in bargaining power explain the apparent conflict.

### Experimental Results

Figure 4. shows the cost structure of the experimental model together with the resulting trading prices received by weight groups. The curves plotted in Figure 4 were derived by fitting quadratic functions through the experimentally generated break-even and negotiated trading price generated in 48 rounds of trading with approximately 40 transactions per round. Thus a total of nearly 2,000 observations were obtained. The packer and feedlot break-even price curves and resulting equal profit curve are of the same shape as observed in Figure 3, except they have shifted in height to capture the average price levels occurring during the game. The key point to note with regard to Figure 4 is that the quadratic curve fitted to experimentally generated set of slaughter cattle prices is convex to the x-axis while the equal profit curve is concave to the x-axis, i.e. the weight axis.

Table 3 below presents an explanation of the reversal of curvature between the equal profit curve and the experimentally generated weight/slaughter price curve. Table 3 presents the weighted average values of "bargaining power indices" for 1125, 1150, 1175 and 1200 pound cattle. These indices were developed by calculating a bargaining index value for each weight group of cattle during each trading period. For each weight group of cattle traded during each trading period the potential profit (or loss) available was calculated based upon the feedlot and packer break-even price for that period. The average negotiated slaughter price for the period was then used to determine the percentage of available profit captured by feedlots. This percentage was multiplied times 100 to form an index. Thus an index value of 50 indicates the feedlots received half (50 percent) of the available profit for a given weight group of cattle, while an index of 100 indicates they captured all of the available profit. Likewise an index value of 0 would indicate that the packers captured all of the available profit. A negative index value implies that feedlots were losing money while packers were making money. Losses were treated in a similar manner with an index of 50 implying losses were equally shared between the feedlots and packing companies. After index values were calculated for each weight group during each trading period, values for each weight were aggregated across all trading periods according to the volume of slaughter in each trading period. The resulting values are reported in Table 3.

Table 3. Weighted Average Bargaining Power Index Values by Weight

	1125	1150	1175	1200
Mean Value	42.9	35.7	3.5	-39.4
Standard Deviation	10.4	9.0	14.9	42.7
Number of Transactions	210	860	454	261



The values in Table 3 show two things. First, packers seem to have had superior bargaining power in the experiment conducted, and second feedlot bargaining power declines as cattle increase in weight. The reasons for packers having superior bargaining power will be discussed presently. The reason for the decline in feedlot bargaining power as weight increases is critical to analysis of the weight/price relationship of interest here. It is rationalized as follows. Both packers and feedlots know the best weight to buy/sell cattle at is 1,150 pounds. Furthermore feedlots know their break-even price falls until a weight of 1,150 pounds. Thus feedlots will not be prone to sell 1,100 or 1,125 pound cattle unless they can receive a strong price bid from a packer. Hence their bargaining position is strong for these two weights. This fact resulted in there being no transactions during the experiment involving 1,100 pound cattle. When cattle weigh more than 1,150 pounds, feedlots lose considerable bargaining power for two reasons. First, their break-even price begins to rise, and second they are approaching a point where they will lose their market for their cattle, i.e. when cattle reach a weight of 1,225 pounds they can no longer be bought by one of the packers in the experiment (i.e. in reality by a major boxed beef packing plant). Sale must be to the experiment management at a considerable discount. Both parties know this fact, thus it places the feedlot at a disadvantage, especially when the negotiation is for 1,200 pound cattle that will be automatically heavily discounted in the following iteration if not sold in the current period. Packers realize that despite being able to pay a higher price for 1,200 pound cattle they do not have to.

### Causes of Shifts in Bargaining Power

Preliminary investigation into the causes of shifts in bargaining power during different phases of the experiment have been conducted. Figure 5 shows the pattern of a composite feedlot bargaining index over the course of 48 trading periods. The composite index was formed from a weighted average of the bargaining power index for each weight group during a given trading period. A seven-period moving average of the index was used because the index tended to be volatile during periods when profit was very close to zero, i.e. when profits were \$.50 per head it is not uncommon for one firm to make \$2.50 per head while the other loses \$2.00 per head, thus yielding index values of 500 and 400 respectively.

In observing Figure 5, the feedlot bargaining power index in general weakened over the period of the experiment. A reversal in bargaining strength appears to be beginning near the end of the period. The experimental market computer record system is rich with data which can be used to attempt to explain the general decline in bargaining power throughout the experiment. Weekly (individual trading period) data on showlist size, marketings, placements, bargained cash slaughter price, boxed beef price, and the average weight of cattle on the showlist are data series that are available to attempt to explain the observed pattern of the composite bargaining power index series.

Of the aforementioned variables, the only one found to have robust properties in explaining bargaining power was the average weight of animals on the showlist. A non-linear relationship was found between the composite bargaining power index and the average weight of cattle in the showlist. Specifically bargaining power decreased at an increasing rate as average showlist weight exceeded approximately 1,130 pounds. This result is very consistent with the information presented in Table 3.

Contrary to a priori expectations showlist size and marketings were not significant variables in explaining feedlot bargaining power. A priori one might expect large marketings and large showlists to decrease feedlot bargaining power. If any relationship was found to exist between marketings and bargaining power it was that increases in marketings were associated with increases in bargaining power. Numerous explanations can be offered for the lack of a robust relationship between bargaining power and marketings and showlist size. One explanation is that the dynamics of the relationship between these variables (i.e. leads and lags) and the bargaining power index have not been properly captured.



Alternatively the possibility exists that no robust relationship exists between these variables. In retrospect the latter conclusion may be consistent with some strongly held industry views. The common theme among feedlots is to "stay current". This implies that cattle should be sold before they become overweight or "backed-up". The results obtained here indicate that large showlists lead to lower prices, but not necessarily to a smaller percentage of the lower profits resulting from low prices. Thus large showlists that are not a result of overweight cattle are indicated to not be a bargaining power problem. Likewise large marketing volume that is not driven by the presence of overweight cattle are not indicated to be a detriment to the feedlot's share of available profit. Indeed when feedlots are able to "move cattle" by achieving large marketing volumes it enables them to avoid "backing up" cattle. Thus the ability to market large volumes of cattle and avoid significant inventories of relatively heavy weight cattle can be rationalized as an action that enables feedlots to create a bargaining power advantage.

### Conclusion

Analysis of feedlot closeout data for approximately 35,000 pens of cattle indicates that a nonlinear relation exists between slaughter weight and slaughter price. Specifically, slaughter steer prices were found to reach a maximum at about 1,075 pounds and to begin to fall rapidly at weights over 1,200 pounds.

Analysis of the break-even price structure for feedlots and packing plants found that the economic value of cattle should continue to rise until cattle reach weights in excess of 1,200 pounds. If packers and feedlots negotiate prices that equally divide the available profits (or losses) for slaughter cattle an upward sloping slaughter weight/price relationship would exist to a weight of at least 1,200 pounds. Thus the perceived cost structure of the fed cattle industry implies the pattern of economic values of slaughter cattle by weight is inconsistent with the pattern of observed prices received by weight.

Experimental economics was used to explain this apparent conflict. Experimental economics results indicate that the bargaining power of feedlots steadily declines as cattle reach heavier weights and feedlots receive smaller and smaller percentages of the available profit. Thus the experimentally generated weight/price relationship reaches a maximum at about 1,125 pounds (similar to the curve estimated from actual closeout data) while the experimental cost structure curve indicating the value of cattle by weight (assuming equal sharing of profits by packers and feeders) rises steadily as slaughter weight increases.

The major conclusions drawn from this study are that slaughter cattle prices at different weights are influenced as much, if not more, by bargaining power factors than physical cost and quality factors. In anticipating the impact of retaining cattle on feed to heavier weights, feedlot operators should be as concerned with the bargaining situation this generates as they are concerned about the physical impacts of such a decision.

Figure 1. Slaughter Weight and Price Relationship  
(Based on Actual Closeout Data)

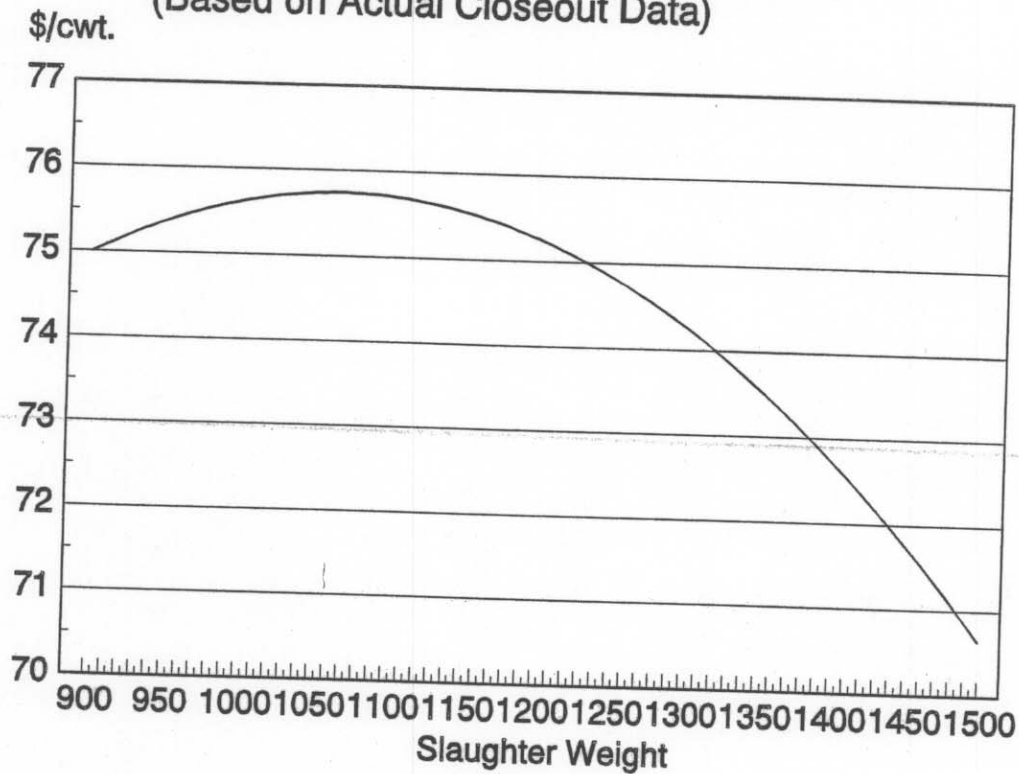


Figure 2. Meatpacker Average Cost Curves

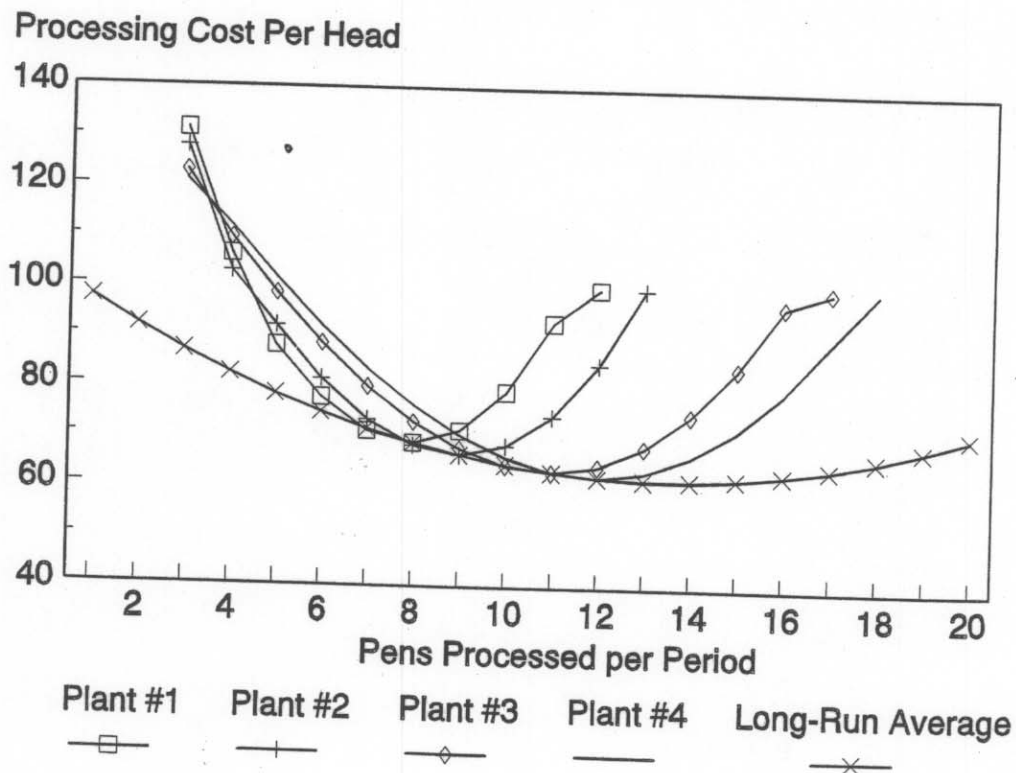


Figure 3. Typical Break-even Price Relationships

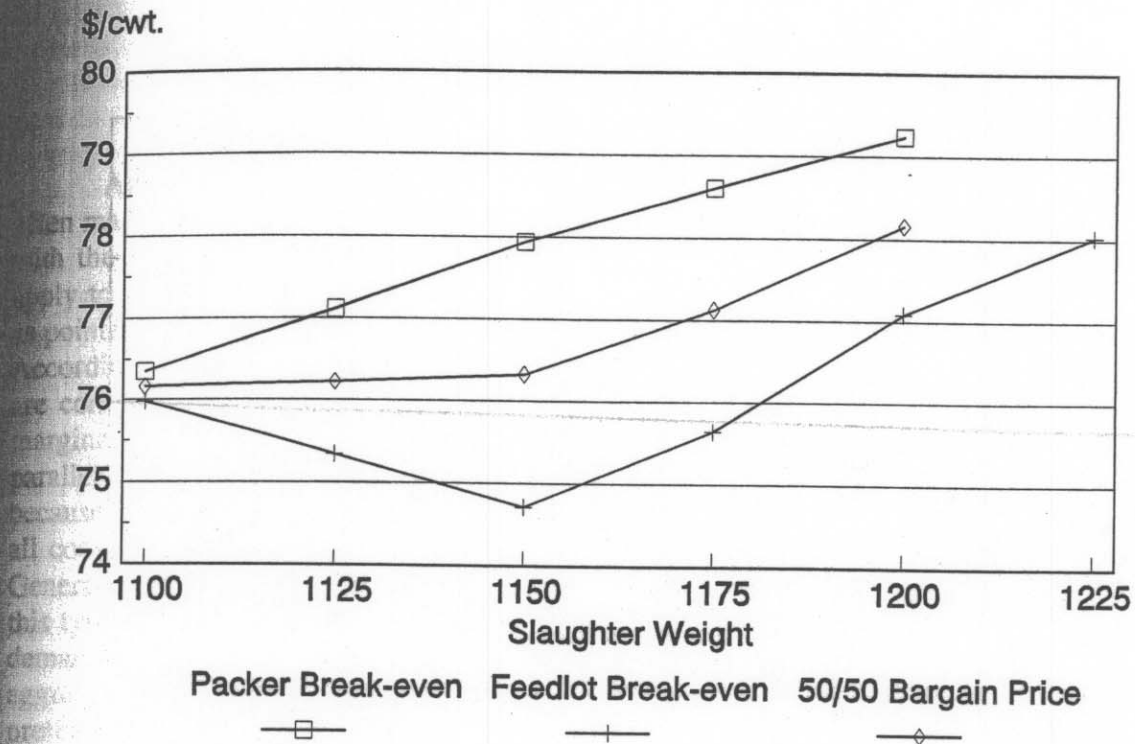


Figure 4. Prices vs. Slaughter Weight

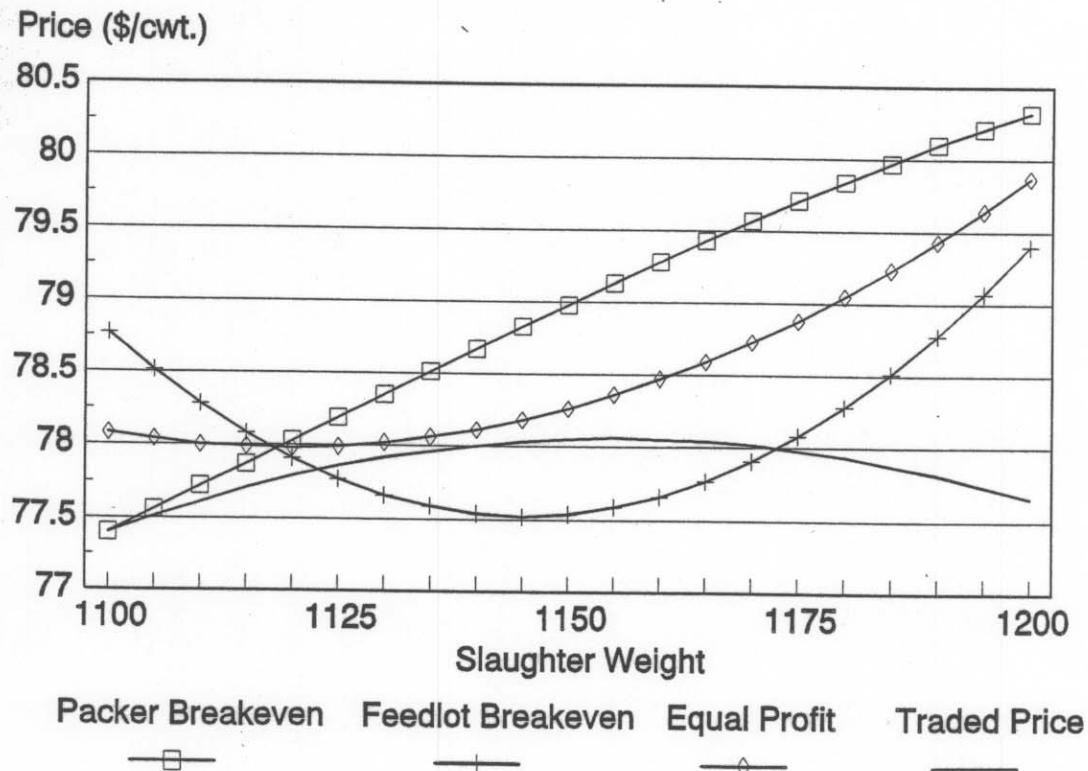
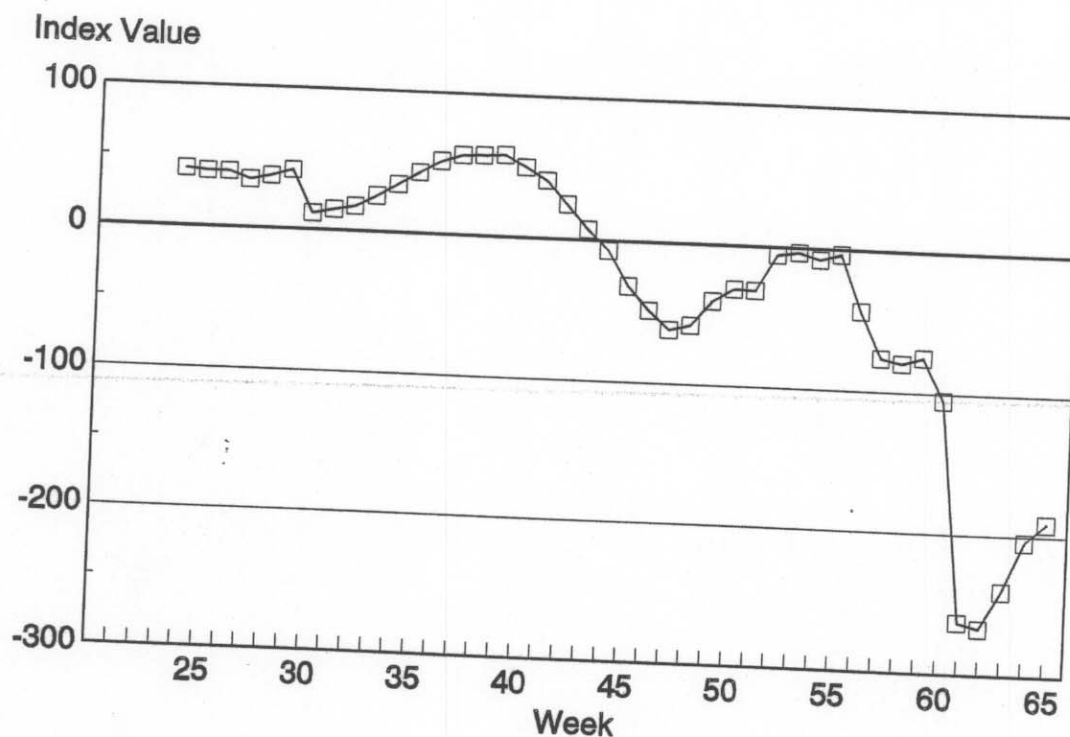




Figure 5. The Bargaining Power Index (7-Period Moving Average)



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