Lessons Learned from Research with the *Fed Cattle Market Simulator*

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Structural and behavioral changes and their implications for price discovery have been significant concerns to many in the beef industry for at least two decades. However, structural changes, e.g., increased consolidation and concentration, make it more difficult to access necessary data to conduct some types of relevant research related to these issues. As a result, the co-authors of this paper began meeting regularly in 1989 to discuss common livestock marketing research and extension interests. At the time, all were in the Department of Agricultural Economics at Oklahoma State University (OSU). Two were new assistant professors and two had several years experience addressing various livestock marketing issues. From those early meetings came a desire to develop an experimental research tool to address beef industry issues that might otherwise be difficult to address because of data limitations.

The result was the *Fed Cattle Market Simulator* (*FCMS*), quickly dubbed the "packer-feeder game" by OSU students. Since then, the market simulator has been used in the threefold mission of the Land Grant University system, i.e., teaching, extension, and research. This paper summarizes and compares research done with the market simulator and data generated by it, then provides observations on use of the experimental market for research.

Overview of the Simulator

Structural features of the *FCMS* can be found in various publications (e.g., see Ward et al. 1996), so only essential components are reviewed here. From the outset, the focus of the *FCMS* was on the price discovery process for fed cattle. Participants, whether students or adult learners, work in teams of two-to-four persons. There are eight cattle feedlots and four meatpacking firms. The feedlot teams are instructed to market fed cattle at a profit, and meatpacking teams are instructed to purchase fed cattle at a profit. Half-sheets of paper, each representing 100 head of fed steers, are bought and sold by feedlot marketing managers and beefpacking buyers. Predetermined cattle supplies are programmed into the software written exclusively for the simulator. Supplies are meant to mimic the cattle inventory cycle of the beef industry.

Cattle are placed on feed at 700 pounds, gain 25 pounds per week, and are ready to be sold between 1100 and 1200 pounds. During that five-week marketing window, cattle are on the "show list" and packer buyers approach feedlots to bid on cattle. Packers operate different size plants with different cost structures, just like packing firms in the real fed cattle market. Packers know how many pens of cattle they need to operate their plant efficiently at the minimum-cost volume. Packer buyers begin with the boxed beef price and estimate their breakeven price before bidding. The boxed beef price is determined by the level of trading in the simulated market.

Feedlot marketing managers estimate their breakeven prices and arrive at an offer or counter-offer price. Feedlot managers understand they can market cattle at 1150 pounds, where their breakeven price is lowest. However, there are times they may choose to market lighter or heavier cattle. If they market cattle at heavier weights, they are penalized for over-finishing the cattle. Packers on the other hand prefer heavier cattle because slaughter and fabrication costs are the same per head for cattle of any weight, but costs are less per pound for heavier animals.

Feedlot marketers and packing plant buyers negotiate the sale/purchase price for each pen of cattle. They use information supplied to the market, much like information from the Agricultural Marketing Service (AMS) and National Agricultural Statistics Service (NASS) of the U.S. Department of Agriculture (USDA). A simulated trading week of seven minutes corresponds to one week of real-world business by feedlots and packers. Teams can trade cattle with fixed-price forward contracts if they so choose. The simulator also has a futures market. Teams can trade three futures market contracts, i.e., one nearby contract and two distant contracts. Thus, teams can hedge cattle sales and purchases, or trade cattle with basis forward contracts.

At times, feedlot and packer teams share profits available to the industry. However, at other times, feedlots and packers must share losses, depending largely on cattle inventory numbers. How well individual teams do depends in part on their negotiating skills. Teams are recognized or rewarded with travelling "trophies" for how profitable they are. The most profitable team each four weeks receives the prized (?) team trophy, a well-worn loving cup for third place at the 1924 Montana State Horseshoe Tournament. The best supporting team (there are no losers!) receives a homemade "trophy," a gold-'n-silver, cow-chips-on-a-shingle (yes, real cow chips in a sealed plastic bag) for their assistance in supporting the most profitable team.

Development Highlights

The *FCMS* was first offered as a special problems course in the fall semester 1990 while the simulator was still in the early development phase. The developers received a Higher Education Challenge Grant from USDA the following year, which was key to full development of the simulator. The grant enabled writing an upgraded version of the software and simultaneously improving the hardware components. Both aspects contributed to the effectiveness of the simulator. A later grant from the Chicago Mercantile Exchange enabled enhancing the futures market component of the simulator.

The first extension workshop using the simulator was with employees of Excel Corporation in 1992. The simulator was initially conceived as an experimental economics research tool but it was used mostly in is early years for classroom teaching and extension education. Writing research papers from data generated by the simulator began in 1994. Another grant, this time from the Research Institute on Livestock Pricing, enabled the developers to conduct the first formal, "laboratory" experiment with the *FCMS* in 1995. At this point, the simulator was being used in all three missions of the Land Grant University system.

Research Applications

Five formal experiments have been conducted with the market simulator. In addition, data generated by the simulator have been used to address four other related research questions. What follows is a synopsis of each research project in approximately the chronological order in which each was conducted. The brief summary is supplemented by Table 1, which identifies several elements of each study, including brief findings.

The first formal experiment involved estimating the impacts from imposing a marketing agreement onto the market (Ward et al. 1999). The largest packer agreed to purchase all fed cattle marketed by the two largest cattle feedlots. The agreement lasted 16 weeks and was replicated for another 16 weeks after an interval of having no formal agreement in place. The teams involved in the marketing agreement were instructed to share profit and loss statements and any other pertinent information in negotiating a profit-sharing price for cattle traded under the agreement.

The second experiment involved assessing the value of information in the price discovery process and the effect of reduced market information on marketing efficiency (Anderson et al. 1998b). Varying degrees of market information, i.e, within-week market information and end-of-week market summary information, were provided to feedlots and packers in a predetermined experimental design. Periods of reduced information varying in random lengths from 4-8 weeks were interspersed with random periods of 4-8 weeks in which normal amounts and kinds of information were available to the experimental market.

A third experiment examined impacts from imposing mergers between packer teams (Ward and Lee). This experiment was conducted with two large agribusiness firms, one a large meatpacking firm and one a large cattle feeding firm. In one case, the two smallest packers in the experimental market were merged; and in the other, the two largest packers were merged. In both cases, the mergers lasted 10 weeks and were sandwiched between a 10-week pre-merger period and a 10-week post-merger or dissolution period. Merged teams were instructed to operate their meatpacking firms as a multi-plant (two-plant) operation.

Another experiment estimated the effects from imposing increasing levels of contracting between feeders and packers, from 0% to 88% (Lyford et al. 2001b). Feedlot teams were instructed to forward contract with specific packers using a formula pricing arrangement tied to the preceding week's cash market price. Each new level of contracting (0, 25%, 50%, 62%, 75%, and 88%) lasted eight weeks.

Lastly, an experiment was designed to determine the pricing and marketing efficiency impacts from mandatory price reporting (Bastian, Koontz, and Menkhaus). Forward contract price information (volume and price range) was made available to participants during the 32 weeks for which data were collected. Prior to mandatory price reporting, AMS treated contracts as private transactions and did not collect or disclose contract price information. Normally-reported information in the experimental market remained available to participants during the study period.

Other research was conducted with data from the market simulator. When software for the simulator was written, the developers planned a means to archive and "capture" data generated by the simulator for later analysis. For example, data were collected from semester-long periods or workshops but no "formal" experiment was conducted. Then the data were used to address industry issues.

Initially, data were used to compare price discovery in the *FCMS* with price discovery research using real-world data (Ward et al. 1996). A price discovery model was estimated with experimental market data and compared with similar models estimated with industry data.

Another study estimated economic gains from vertical coordination under alternative marketing and purchasing strategies (Anderson et al. 1998a). Total industry profit from alternative, simulated strategies were compared with profits generated by students in a semester-long class.

A procedure to evaluate the accuracy or precision of reported prices was demonstrated with data from the simulator (Ward and Choi). Data from a semester-long class were treated as the population of reported prices. Then various methods were employed to reduce the set of available reported prices, mimicking reductions in reported prices in the real-world market. The accuracy of reported prices from each sample was compared with the population of known reported prices.

Lastly, *FCMS* data enabled examining the relative negotiating strength of feeders and packers in the price discovery process under alternative supply conditions (Lyford et al. 2001a). An index of negotiating strength was developed and a model explaining the variability in the index was estimated.

Table 2 provides a comparison (where applicable) of selected variables and models that were estimated in the above-described studies. The column labeled "Price Discovery" represents the first model using data from a semester-long class and is sometimes considered a "base" model and data period. The other four models resulted from experiments. Note that blanks indicate the variable was included in the model but was not statistically significant; whereas, NA denotes variables not included in that respective model.

Readers can study and evaluate for themselves how consistent or inconsistent the coefficients were across models, data periods, and participant groups. One interpretation is offered here. Signs and significance were relatively consistent for the price determining variables, i.e., boxed beef prices and futures market prices along with total show list inventory and weekly marketings. The potential profit variable has been a much-questioned variable among journal reviewers and consistency of its coefficient sign and significance has been less than other continuous variables.

Dummy variable coefficients for cash vs. contract trades have been quite consistent. Less consistency was found for the weight variables. Similarly, coefficients for feedlot and meatpacking firms (teams) does not appear to be highly consistent, perhaps as expected. Each group of simulator participants is a bit different than others and those differences would logically be reflected in the comparative performance of each team to the others, thus leading to differences in feedlot and meatpacking team coefficients.

Some of the dummy variables unique to specific studies are shown in Table 2. However, perhaps little can be gleaned from comparing them across models.

One nagging question researchers and reviewers have regarding the market simulator, and differences among participating groups, is the consistency of market performance. Table 3

provides some insight into that question, using summary statistics on prices and volumes for three semester-long classes (Carlberg and Ward). Mean prices and volumes for the market as a whole (i.e., all packers) were not significantly different, nor were any significant differences found for individual firms (teams). Individual groups have an identity and can certainly influence short-run market performance. Yet, while data in Table 3 cannot be judged conclusive, statistics suggest long-run market performance is predominantly group-insensitive.

Lessons Learned

Several observations can be made regarding the ten-year experience from using the *FCMS* for teaching, extension, and research. Comments focus largely on using the experimental market for research.

For classroom teaching and extension education, the *FCMS* is extremely well-received and effective based on feedback from students and adult learners. Students and adults really like the hands-on, experiential learning nature of the simulator. "Lived" concepts and experiences stay with them far longer than textbook sections or lectures over the same concepts. Limitations for teaching involve the instructor time to set up and take down the equipment each class period. A similar limitation exists for extension but also includes transporting the equipment to extension education sites. For extension meetings, too often potential organizers and participants cannot conceive of a day-long or longer workshop led by two-to-four economists. As a result, too little time is allotted to *FCMS* workshops to achieve closer-to-optimal or maximum learning.

Regarding research, four observations can be made. Three are endogenous to the simulator and one is exogenous. The endogenous characteristics follow first.

1. The *FCMS* is time intensive. Typically, for research experiments, workshops of 8-12 hours and classes of 18-20 hours of trading are required.

2. Related to the above, the *FCMS* is resource intensive, not so much in dollar terms as in human resources. Classes and workshops typically require two instructors at a minimum and up to four instructors for intensive, two-day workshops. A minimum of 24 participants are required (two people per team) and 36 are preferred. A practical maximum number of participants is 52 (four persons per team plus four futures market speculators).

3. Elements of the experimental market as designed are highly structured and relatively rigid. This rigidity limits some desired adjustments to groups or situations. And it does not lend itself to some types of research experiments. On more than one occasion, economists or industry participants have asked if we have researched some topic that seems applicable given their knowledge of the experimental market. However, when considering the detail of the research and how it would be approached in a designed research experiment, the *FCMS* proves to be inadequately flexible to undertake the research.

The exogenous lesson involves convincing persons with limited knowledge and no experience with the simulator that the experimental market is a reasonable facsimile of the real fed cattle market and that data generated are comparable to industry data. This point has been especially

troublesome and frustrating in trying to publish journal articles from research with the *FCMS*. While the list of references suggests some publishing success, it hides the difficulties faced with editors and reviewers in some cases. Journal reviewers frequently suggest changes that cannot be made without another semester-long class or extension workshop with another group of participants. Analogous to growing-season experiments or life-cycle experiments in plant and animal research, reviewers at times would like one more repetition.

It has been difficult at times to convince some reviewers that behavior of participants resembles behavior in the real fed cattle market. Participants consistently provide feedback on how similar market conditions are in the experimental market to the real fed cattle market in which they "live" daily. Conveying this type of anecdotal evidence of data reliability is difficult. The authors' experience suggests convincing reviewers of the reliability of experimental market data and results is far more difficult than conducting research with questionably reliable, but publicly collected and published, data.

Similarly, reviewers have difficulty understanding that people are the core ingredient to our experimental market and that the *FCMS* is not just computer software. The *FCMS* is a blend of experimental economics and business simulation software. Frequently, reviewers suggest we run the simulation again to collect different data, just as one would with a computer simulation program.

Future Plans and Concluding Remarks

Changes are anticipated for the *FCMS*. One shortcoming of the experimental market has arisen because the real fed cattle market changed dramatically during the past decade. The industry has moved more rapidly than anticipated toward value-based pricing, i.e., typically called grid pricing. Consequently, efforts are underway to rewrite the *FCMS* software, changing the parameters of the simulator to encompass grid pricing. This simple-sounding modification is complicated by the fact that the software now must incorporate within-pen carcass performance variability. Up to now, carcass characteristics were the same for each weight of cattle marketed. These changes will enhance the realism of the marketing and procurement decisions faced regularly by feeders and packers, respectively. It will also provide an opportunity to teach decision-making in a manner unlike what has been done previously.

Too, computer technology has changed rapidly. Further software changes are needed to make the simulator compatible with Windows-based software and with newer hardware technology.

Despite some frustrations and limitations, the evidence suggests development and use of the experimental market has been worth the time and effort, for developers and participants alike. Seven other universities have used the experimental market for classroom teaching and extension education. They are: Kansas State University, Iowa State University, Texas A&M University, Texas Christian University, University of Kentucky, Colorado State University, and South Dakota State University. The *FCMS* has been an excellent teaching tool as well as useful research tool. Estimated development costs for the market simulator were about $250,000 with extramural funding providing about 40% of those investment costs. Not every institution can, or should, invest that amount of resources into developing an experimental market. However,

multi-institutional collaboration seems appropriate, desirability, and potentially workable. If done in a truly integrated manner, i.e., not multi-institutional in name only, each institution would share significantly in the investment costs, would view itself as a stakeholder in the final product, and would use the final product to achieve net benefits, i.e., benefits exceeding the sunk costs.

A more generic version of the *FCMS* would likely be well accepted by a broad array of agricultural economics departments. With the focus on agribusiness management, an experimental market that combines many of the proven features of the *FCMS*, perhaps with more emphasis on management, could be a highly effective teaching tool. The *FCMS* differs from but is a combination of "true" experimental economics and from "traditional" business simulation. Thus, a multi-institutional proposal for extramural funding would likely be well-received if done correctly. One key is having an effective leader and lead institution. Another essential is having highly coordinated, integrated involvement by committed individuals from several institutions.

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Table 1. Summary of Research with the *Fed Cattle Market Simulator*.

Research Project	Data Source	Data Aggregation Observation	Trading Weeks	Findings
Fed cattle price discovery	OSU class, 1994	Transactions, 2,682	30-101	"Generally" consistent with previous research using real-world data. Emphasized the human element in market performance
Marketing agreement: Impacts*	OSU class, 1995	Transactions, 2,770	40-114	Higher prices during agreement periods Increased price variation during agreement periods
Value of public market information *	OSU class, 1996	Transactions, 2,197	37-96	Increased price variation with reduced information. Reduced marketing efficiency (non-optimal weights) with reduced information.
Vertical coordination benefits	OSU class 1995	Weeks, 70	29-98	Higher industry profits realized from non-price coordination strategies. Largest gains were related to following structural parameters of the market simulator
Price reporting accuracy	OSU class, 1994	Transactions, 2,515	30-101	Little loss in price reporting accuracy as transaction numbers were reduced
Meatpacking firm merger impacts *	Agribusiness Workshops	Transactions, 1,062	41-70	Higher prices during merger periods. Relative profits were higher for the merged firms
Negotiating strength of buyers/sellers	OSU classes, 1994-96	Transactions, 2,416***	32-100***	Negotiating strength favored feeders when supplies were light. Negotiating strength favored packers when supplies were heavy
Extent of contracting *	OSU class, 1999	Weeks, 58	25-82	Higher contracting associated with lower prices. Higher contracting associated with inconsistently higher or lower price variation
Mandatory price reporting impacts *	CSU class, 2000	Transactions, 2,721	32 (total)	Additional information on forward contracting associated with lower, less variable cash prices and higher contract prices. Additional information associated with increased marketing efficiency (optimal weights)

* Formal experiment

** OSU is Oklahoma State University, CSU is Colorado State University

*** Average of transactions and trading weeks for three semesters

Table 2. Model Variables and Significant Coefficient Comparisons in *Fed Cattle* 'Market Simulator Research*

Variable Group and Variable	Price Discovery	Marketing Agreement	Value of Information	Merger Impacts**	Mandatory Price Reporting
			$/cwt.		
Continuous Variables					
Boxed beef price (t-1)	0.499	0.312	0.235	0.090	0.250
Futures market price (t-1)		0.279	0.436	NA	0.327
Showlist inventory (t)	-0.042	-0.054	-0.070	-0.100	-0.876
Marketings (t-1)		-0.057	0.082	-0.150	-0.103
Profit potential (t)	-0.555	-0.127		0.100	
Common Dummy Variables					
Weight 1100 lbs.	-0.658	NA	NA	1.080	NA
Weight 1125 lbs.	-0.281	NA	NA		NA
Weight 1150 lbs.	Base	NA	NA	Base	NA
Weight 1175 lbs.		NA	NA	-0.980	NA
Weight 1200 lbs.	-0.478	NA	NA	-1.580	NA
Cash trade	-0.348	NA	NA	Base	Base
Contract trade	Base	NA	NA	0.360	-0.266
Feedlot 1	Base	Base	Base		Base
Feedlot 2		0.215	0.572	-0.400	0.268
Feedlot 3	-0.109	0.659	0.375	-0.690	0.374
Feedlot 4	-0.134	0.396	0.960	-0.530	0.213
Feedlot 5	-0.337	0.405	0.678	Base	0.362
Feedlot 6	0.121	0.454	0.481	-0.420	0.196
Feedlot 7		0.368	0.813		
Feedlot 8			0.459	-0.910	0.597

Table 2. Model Variables and Significant Coefficient Comparisons in *Fed Cattle* 'Market Simulator Research* (cont)

Variable Group and Variable	Price Discovery	Marketing Agreement	Value of Information	Merger Impacts**	Mandatory Price Reporting
Packer 1	Base	Base	Base	-5.870	Base
Packer 2	-0.378	-0.409	0.152	-5.930	
Packer 3	-0.214	-0.500	0.123	-6.040	-0.087
Packer 4	-0.123		0.404	-6.780	0.159
Unique Dummy Variables					
Pay periods	NA		1.193	NA	NA
Non-pay periods	NA	Base	Base	NA	NA
Marketing agreement periods	NA	1.212	NA	NA	NA
Non-marketing agreement periods	NA	Base	NA	NA	NA
Information periods	NA	NA		NA	NA
Reduced information periods	NA	NA	Base	NA	NA
Information period	NA	NA	NA	NA	Base
Additional information periods	NA	NA	NA	NA	-1.058

* Blanks indicate variable was included but not significant (0.10 or lower). NA indicates variable was not included in this model.

** Packer coefficients were averaged across pre-merger, merger, dissolution periods. Coefficients are for the merger of Packers 1 and 2.

Table 3. ANOVA Results for FCMS Prices and Volumes, 1994, 1995, 1996

Variable	Team	1994	1995	1996	p-Value
Price ($/cwt).	Packer 1	78.72	78.75	78.14	0.60
	Packer 2	78.28	78.34	78.10	0.94
	Packer 3	78.52	78.50	78.29	0.92
	Packer 4	78.75	78.69	78.66	0.99
	All Packers	78.67	78.66	78.42	0.91
Volume (Pens)	Packer 1	7.8	7.8	8.0	0.76
	Packer 2	8.1	8.3	8.7	0.38
	Packer 3	10.5	10.6	10.6	0.99
	Packer 4	12.0	11.6	11.9	0.55
	All Packers	36.6	36.8	36.7	0.98