Marginal Value of Quality Attributes for Natural (Organic) Beef

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Consumers are increasingly demanding food products possessing specific attributes related to production and/or processing (Barkema; Streeter, Sonka, and Hudson). One such attribute is increasing demand for natural beef products. Producers have responded by attempting to meet the demand through organized alliances. Givry found over 30 producer-owned cooperatives or private firms marketing organic or natural beef in the United States in 1998.[1] Many beef producers are considering making investments in organic or natural beef production systems and marketing cooperatives to provide beef products to consumers.[2] The USDA Small Farm Commission Report indicated that market research is a critical need for producers in these type of systems. Because organic or natural producers market animals that may possess any combination of multiple attributes (e.g., organically grown, produced on small farms, no synthetic growth promotants, etc.) using contracts (e.g., Laura's Lean Beef, Coleman, etc.) or through cooperatives (e.g., Tall Grass Prairie, All Natural Beef, etc.), it is important that they have information on which attributes are most valued by consumers.

Some attributes (like breed, marbling, etc.) may be attainable through production practices such as genetic selection, becoming certified organic, or feeding grain or grass in the finishing ration. Other attributes valued by consumers might include tenderness or pasteurization labeling which are at least influenced through processing practices such as dry aging or irradiation, respectively. The value of the attribute has implications for a producer's decision to invest in a cooperative. This could help avoid potential moral hazard problems which arise in an agency theory framework whereby a firm contracts with a producer for beef with certain attributes using some premium over a commodity price but the producer does not know which attributes are most highly valued. Consequently, producers may make investments in production assets or systems

that may not be needed.

Natural or organic beef and conventionally produced beef are examples of product differentiation. The product (e.g., beef) is the same across production systems but its price may differ because producers use different production methods and consumer demand varies by production practice. The variety of attributes (e.g., conventional, natural, organic, etc.) for beef products is characteristic of differentiation. The value of these attributes can be estimated by using hedonic price functions. The objective of this research is to determine the marginal value of attributes valued by consumers with respect to natural beef or beef produced with organic grains and sold by producers in a chain of Midwestern supermarkets.

Background Information

The demand for beef has declined since the late 1970s (Purcell). Lusk et al. in reviewing the literature on factors contributing to the decline in beef demand noted that changes in relative prices, consumer health concerns, food safety concerns, product convenience and offering, product quality and consistency, changing demographics, and evolving consumer preferences are significant factors explaining this decline. Schroeder, Marsh, and Mintert found that many of these factors adversely affected beef demand especially vis-a-vis competing meats. However, many of these factors cannot be changed solely by producers, processors, or retailers (Smith et al.). Integrated or tightly coordinated beef production and processing systems are able to respond to economic incentives for various product quality attributes more readily than the traditional cash market system (Schroeder et al.).

Producers

Beef producers are able to make improvements in genetics through selecting for traits such as increased feed conversion to reduce per unit production costs or enhance marbling to increase per unit marketing revenues. Similarly, a producer may decide to not use cost-reducing technologies such as synthetic growth promotants or subtherapeutic antibiotics if economic incentives exist to produce natural beef products.

The choice of breeds is another way for a producer to enhance revenues. The CERTIFIED ANGUS BEEF™ program has doubled in size since 1995 (to almost 500 million pounds). Producers who qualify for this system are required to meet certain production quality criteria which are correlated with various desired consumer attributes such as leanness and muscling. Other breed programs have similar features. The value-based marketing programs used by breed associations are often based on USDA grades rather than linked to specific consumer attributes (Sartwelle).

The choice of farming system is another factor producers may use to enhance revenues. Economies of size and scope exist among various enterprises (e.g., cow-calf production, feedlot) and a producer may choose a production system that utilizes more labor than capital (e.g., cow-calf to finishing). But it is unclear whether consumers will provide economic incentives for these systems so as to provide additional revenue to offset potential higher production and processing costs. Organic certification vis-a-vis natural beef labeling may be a valuable attribute to consumers.

The choice of feed ingredients is another controllable factor. Grain has long been known to increase marbling in beef relative to a ration of only pasture grasses. Thus, grain-fed beef may have a greater value to consumers because grain-fed beef tends to have more marbling.

Processors

Many of the factors affecting beef demand were related to product quality attributes. In particular, lack of tenderness is one such attribute commonly cited by processors and retailers (Smith et al.). Many studies have found that tenderness is the most important attribute of beef palatability (Dikeman; Huffman et al.). Tenderness is a function of several things including genetics, length of time cattle are fed, processing, aging, and product cooking and preparation (Miller et al.). Beef processors have numerous techniques they can use to influence beef product tenderness including aging and various methods of mechanical tenderizing.

Wet-aged or vacuum-packaged beef has been the industry standard since the development of commercial vacuum-packaging technology in the late 1960s. This has decreased processing costs due to lower inventory costs. Dry-aging is more costly relative to other conventional processing methods but the process does tenderize beef naturally (Huffman et al.). However, the additional time required in refrigerated coolers and estimated shrink loss of at least 10 percent significantly increases the cost of producing dry-aged beef.

The current USDA quality grading system uses intramuscular fat or marbling as a primary measure of quality. However, this is poorly correlated with tenderness (Wheeler, Cundiff, and Koch). Consequently, tenderness or similar attributes have not been a component of most beef value-based marketing programs. However, several technologies exist that have potential for measuring tenderness and could be used in a value-based marketing program **(**Miller et al., Shackelford, Wheeler, and Koohmaraie).

Schroeder, Marsh, and Mintert found that a large increase in the number of beef recalls results in a significant decline in beef demand. Although it is difficult to obtain quantitative evidence on consumer attitudes towards food safety concerns, traceability or identity-preservation

has clearly become a more important attribute in recent years. Labeling beef which has been produced under such systems may help alleviate consumer concerns over safety.

Theoretical Model

Waugh was probably the first to identify the value associated with quality factors. He analyzed variations in price and correlated quality factors such as size, color, weight, and condition in asparagus, tomatoes, and greenhouse cucumbers. The results suggested that color (green asparagus), condition (firm tomatoes), and length (long cucumbers) were important quality factors.

Gorman and Lancaster developed the demand for product characteristics within a consumer demand framework.[3] Using Gorman's framework, eggs had attributes which make them desirable or undesirable by consumers. For example, Gorman noted that eggs used for baking and eggs used for direct eating would likely have different characteristics. These attributes were not explicitly priced in the market and there was no explicit price for them (e.g., such as diameter, color, etc.). Similarly, beef tenderness or marbling are attributes which have no explicit market price.

Ladd and Martin used consumer demand theory to develop a similar theory for processor demand using profit maximization rather than utility maximization. For example, Ladd and Martin described the value of four carloads of corn based upon five attributes: moisture, test weight, broken and foreign material, damaged kernels, and actual weight.

In this latter framework, inputs are used to produce an product using some production process. For the single output case, output is a function of various inputs such as

Figure 1 $$Y = f(x)$$

where Y is the quantity of output, f is the function operator, and x is the quantity of inputs used to produce Y. These inputs are observable and are composed of attributes which are unobservable. For example, corn and pasture grass are inputs used to produce beef. In reality, these inputs are contain attributes such as marbling (corn) or leanness (pasture grasses) which are valued by consumers. Through substitution of terms in the first order conditions from the utility or profit maximization problem (subject to the previous production function in equation 1) yields the familiar hedonic pricing function which states that

Figure 1 $$P_x = \sum_{i=1}^{m} B_i Q_{ixy}.$$

In (2), B_i is the marginal implicit value of attribute i and Q_{ixy} is quantity of the ith attribute in each unit of input x used to produce y. For beef, (2) states that the observed price of beef is equal to the summed product of the value of marginal product of attribute i (i = color, tenderness, etc.) used to produce y and the marginal yield of attribute i used to produce y from input x. It is commonly assumed that each additional unit of input x contributes the same amount of the ith attribute to produce y (ex., each unit of corn makes an equal contribution to the marbling attribute in beef) and that the marginal implicit price for each i attribute is constant for each unit of x (ex., the price of marbling is the same for all units of corn).

Data

Data on natural and organic beef sales on 630 beef cattle marketed from May 1996 to December 1999 (which represented 100% of all sales) were obtained from a collaborating producer-owned cooperative. The first three months of data (55 carcasses) were not used because of wide

variability in live weight as the program was getting started. Another 97 carcasses had incomplete information. Thus, data on 478 carcasses are used in this analysis.

The beef is sold through a value-based marketing program based upon the weight of the primal cuts. The retailer pays producers wholesale prices for each cut based on a negotiated rate for that week using U.S. Department of Agriculture Agricultural Marketing Service national boxed beef prices. Slaughter and processing are contracted on a per head basis by the marketing cooperative. Producers receive no credit for byproducts but these are used by the processor. The contract processing fee is reduced by the value of byproducts, hide, bones, and similar inedibles.

Producer Data

Producers are required to complete information on each animal marketed through the cooperative as part of their identity-preserved system. The producer variables include *Age* which is the life of the animal measured in months, live weight (measured in pounds), *Days Fed Grain* which is the number of days that the animal was fed a finishing ration to help promote marbling, *Feed Type* or principal type of feed in the finishing ration (corn, barley or milo, haylage), *Breed* type (measured as Angus crosses, Hereford crosses, and other breed crosses), *Gender* (steer or heifer), lot number, *Organic Label* if the animal was produced under a certified organic system, and eartag number.[4]

Processor Data

The cooperative contracts slaughter, processing, and dry aging of the beef with a federally inspected processing plant. The processor variables include *Carcass Weight* which is the hot carcass weight measured in pounds; weight (in pounds) of the primal cuts (Shoulder Clod, Top

Butt, Tenderloin, Flank Steak, Inside Round, Gooseneck, Knuckle, Brisket, Strip, Mock Tender, and Rib Eye), *USDA Grade* measured as Prime, Choice, and Select; and *Number of Days Aged* which represents how long each primal cut is aged (measured as the number of days from slaughter until placed in the retail supermarket counter). Other variables collected but not used in this analysis include the weight of trimmings and ground beef, liver, tail, and other byproducts.

Thus, in this analysis, there are nine variables in *i* (*i = Number of Days Aged, Gender, Breed, Age, Feed Type, Days Fed Grain, Carcass Weight, USDA Grade,* and *Organic Label*) which are used to explain the price of 11 inputs (*x = Rib Eye, Shoulder Clod, Brisket, Mock Tender, Tenderloin, Strip, Top Butt, Inside Round, Gooseneck, Knuckle,* and *Flank Steak*). These 11 inputs determine *Y* which is the live weight of each animal.

Another variable, *Boxed Beef,* was added to *i* to account for changes in price over time. This variable is the Choice 600 to 750 pound U.S. Department of Agriculture Estimated Composite of Boxed Beef Cut-Out Values for that week. Correlations between each of the *i* variables and x inputs was less than .42.

The means, standard deviations, and range for the *i* variables and *Y* (Live Weight) are reported in table 1. In table 2, the wholesale primal cut weights are reported while table 3 presents the wholesale price per pound paid to producers for each primal cut (e.g., P_x). Because some of the variables are not linearly correlated with wholesale price, the natural log of each P_x was used in this analysis. (*Boxed Beef* was also logged). The *i* variables in table 1 (excluding live weight) for each animal were regressed using ordinary least squares on each of the logged wholesale prices in table 3 in order to determine the marginal implicit value of each *i*.

Results

Table 4 presents the parameter estimates ($\hat{a}_i$), standard errors (in parentheses), and coefficient of determination (R^2) for the eleven different equation. Each parameter was tested at the 10 percent level of significance. The relative ability of the variables to explain the variability in the wholesale logarithm of each primal cut price ranged from 0.27 (Mock Tender) to 0.65 (Tenderloin).

It is readily apparent that aging is a significant variable in explaining wholesale prices paid to these producers. *Number of Days Aged* was significant in every model except Inside Round. This result is not surprising given that Givry found consumers ranked taste as the most important attribute of this natural beef. An increase in *Number of Days Aged, ceteris paribus*, yielded an increase in the wholesale price of Rib Eye, Strip, Top Butt, and Inside Round. The largest increase was found for Rib Eye. For example, a one day increase in *Number of Days Aged* (mean was 6.2 days and a one day increase is a 17 percent increase) resulted in a .94 percent increase (.8 multiplied by 1.17) in the wholesale price of Rib Eye (from its mean of $4.04 to $4.30 per pound).

Boxed Beef was also significant in ten models. An increase in the price of the boxed beef composite, *ceteris paribus*, yielded an increase in the price of Rib Eye, Brisket, Mock Tender, Tenderloin, Inside Round, Gooseneck, Knuckle, and Flank Steak. Decreases in the price of Shoulder Clod, Strip, and Top Butt were associated with a price increase in *Boxed Beef*.

A decrease in the wholesale price of Shoulder Clod, Brisket, Mock Tender, Knuckle, Gooseneck, and Flank Steak was found when *Number of Days Aged* increased. These four primal cuts (referred to as "roast beef") have relatively less value per pound relative to higher valued steak cuts such as Rib Eye and Strip. Thus, tenderness (as measured by the length of aging) may not be as important on the overall value of roast beef cuts. The largest decrease was found for Mock Tender. For example, a one day increase in *Number of Days Aged* resulted in a $.0165 per pound decrease in Mock Tender wholesale price (from $1.50 to $1.4835).

The type of feed fed in the finishing ration, *Feed Type*, was also significant in each model except Shoulder Clod and Mock Tender. An increase in the use of barley (or milo) and haylage (rather than corn) yielded a decrease in the wholesale price of Rib Eye, Strip, Top Butt, and Knuckle. The opposite was found for Brisket, Tenderloin, Inside Round, Gooseneck, and Flank Steak.

The two variables that measured time, *Age* and *Days Fed Grain*, were significant in six and four, respectively, of the eleven models. Allowing animals to become more mature (*Age*) would increase wholesale prices for the Shoulder Clod, Brisket, Top Butt, and Knuckle but decrease prices for Tenderloin and Inside Round. For example, the average age of an animal was 21 months. A one month change is approximately five percent and thus, wholesale prices would increase by .4, .8, .8, and .3 percent, *ceteris paribus* respectively. As an animal gets heavier, muscling increases at a faster rate than live weight. Thus, older animals tend to have more muscling which is a desirable trait because many consumers value boneless cuts for convenience in cooking. It is more cost efficient to remove the bone from larger primal cuts of meat.

An increase in wholesale cut prices for Rib Eye, Shoulder Clod, Brisket, Strip, and Top Butt resulted from a decrease in *Days Fed Grain*. A one week increase in this variable (from 193 to 200 days) is a 3.6 percent change. (Note that this would also increase *Carcass Weight*). Rib Eye wholesale prices would decrease .031 percent (1.036 multiplied by .03 percent). Similar percentage decreases for Shoulder Clod, Brisket, Strip, and Top Butt wholesale prices are .082, .002, .04, and .03. respectively.

Carcass Weight, *Breed*, and *Gender* are significant in six, five, and four of the models with very small effects. Likewise, *Organic Label* and *USDA Grade* are significant in three models with very small effects.

Implications

Tenderness, as measured by number of days that beef primal cuts are aged, is a clear indicator of wholesale primal price for the eleven primal cuts purchased by this processor. Given that these prices are derived from retail prices under this particular value-based marketing program, it can be assumed that consumers of this natural beef value its taste. At the present time, there is no value-based marketing program that provides economic incentives for producers and processors to market more tender beef primal cuts to consumers. Rapid and accurate measurement of tenderness is needed to implement a value-based marketing program.

Without information on the value of tenderness relative to other attributes valued by consumers, producers have little incentive to use genetics and production practices that produce tender beef. Dry-aging of beef costs more due to the opportunity cost of inventory, costs associated with refrigeration, and additional labor costs. More efficient methods of tenderization may help reduce these costs in the future. Given the inability to determine an accurate method of valuing dry-aged beef, it is likely that closer coordination between producers, processors, and retailers are needed if this technology is used for large volumes of beef.

Footnotes

[1]These words are often confusing to consumers and producers. Natural is defined by the US Department of Agriculture as "a product containing no artificial ingredient or added color and is only minimally processed (a process which does not fundamentally alter the raw product) may be labeled natural. The label must explain the use of the term natural (such as no added colorings or artificial ingredients or minimally processed)." Organic is in the process of being defined by USDA but is being labeled as "certified organic by (the name of the certifying agency)." The U.S. Department of Agriculture did not allow beef to be labeled as organic until February 1999. However, beef could be labeled as natural.

[2]It should be noted that Greene found that the number of beef cows which were considered 'organic' actually declined from 6,796 in 1992 to 4,429 in 1997. However, this was likely due to the fact that meat could not labeled as organic. Thus, producers did not receive any economic incentives for organic certification. While it is likely that the total number of cattle under organic certification systems increased, producers did not attempt to certify them.

[3]The authors would like to thank Robert E. B. Lucas at Boston University for directing them to Gorman's paper which was an Economics Staff Seminar paper presented at Iowa State University (then called Iowa State College) in 1956 and unfortunately was never formally published until 1980.

[4]USDA regulations require that products which have been certified organic to be labeled as such. Natural labeling has no such certification program and does not require such labeling.

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Table 1. Means, Standard Deviation, and Range for Beef Non-Primal Cut Variables

Variable	Average	Std. Dev.	Min	Max
Live weight, lbs	1179.61	97.36	920	1800
Carcass Weight, lbs	732.01	88.91	520	1034
Age, months	21.21	3.21	15	30
Feed Type[a]	.34	0.68	0	2
Days Fed Grain	193.38	39.64	105	300
USDA Grade[b]	1.48	0.53	0	2
Days Aged - steaks[c]	15.56	1.32	14	19
Days Aged - roast beef	6.2	1.12	5	9
Organic Label[d]	.12	0.32	0	1
Gender[e]	.56	0.50	0	1

[a]Type of feed fed in the finishing ration is a discrete variable where 0 = corn, 1 = barley or milo and 2 = haylage.
[b]USDA grade is a discrete variable where 0 = Prime, 1 = Choice, and 2 = Select.
[c]Steaks are flank, sirloin, tenderloin, rib eye, and strip; roast are shoulder clod, mock tender, inside round, top butt, and gooseneck.
[d]Organic labeling is a binary variable where 0 = organic labeled and 1 = non-organic labeled.
[e]Gender is a binary variable where 0 = heifer and 1 = steer.

Table 2. Selected Statistics for Wholesale Quantities of Primal Cuts (per pound)

Variable	Mean	Standard Deviation	Minimum	Maximum
Rib Eye	22.03	3.47	9.64	51.18
Shoulder Clod	31.16	8.52	7.48	52
Brisket	14.58	4.21	4.57	27.5
Mock Tender	6.02	1.09	2.55	9.67
Tenderloin	10.53	1.75	2.83	22
Strip	22.49	3.88	10.97	37.00
Top Butt	19.83	4.02	2.10	34.35
Inside Round	37.35	6.87	15.62	88.5
Gooseneck	43.74	15.15	15.50	88.00
Knuckle	18.38	2.96	7.96	28.05
Flank Steak	2.73	0.54	0.89	4.97

Table 3. Selected Statistics for Wholesale Prices, P_x (per pound)

Variable	Mean	Standard Deviation	Minimum	Maximum
Rib Eye	4.04	0.62	3.08	5.38
Shoulder Clod	0.98	0.09	0.83	1.25
Brisket	0.90	0.13	0.72	1.23
Mock Tender	1.50	0.10	1.21	1.98
Tenderloin	7.10	1.02	5.14	10.33
Strip	3.00	0.38	2.52	3.75
Top Butt	1.26	0.15	1.05	1.88
Inside Round	1.07	0.11	0.83	1.35
Gooseneck	1.09	0.04	0.86	1.16
Knuckle	1.28	0.1	1.03	1.53
Flank Steak	2.40	0.22	2.12	2.97
Boxed Beef	1.05	.07	0.94	1.20

Table 4. Parameter Estimates, Standard Errors, and Coefficient of Determination for Nine Variables Explaining Wholesale Primal Cut Prices, B_j

Variable[a]	Rib Eye	Shoulder Clod	Brisket	Mock Tender	Tender-Loin	Strip	Top Butt	Inside Round	Goose-neck	Knuckle	Flank Steak
Intercept	1.032 (.104)	.114 (.053)	-.154 (.098)	.575 (.053)	1.953 (.106)	1.049 (.085)	.064 (.067)	-.014 (.061)	.071 (.023)	.204 (.048)	.877 (.034)
Boxed Beef	1.354 (.094)*	-.383 (.062)*	.951 (.089)*	.151 (.048)*	1.154 (.08)*	-.936 (.078)*	-.156 (.078)*	.048 (.07)	.093 (.026)*	.452 (.056)*	1.159 (.04)*
Number of Days Aged	.008 (.004)	-.007 (.004)*	-.011 (.005)*	-.012 (.002)*	-.002 (.004)	.018 (.004)*	.036 (.005)*	.048 (.004)*	-.008 (.002)*	-.015 (.003)*	-.008 (.002)*
Gender	.007 (.012)	.019 (.008)*	-.047 (.012)*	.007 (.006)	.015 (.01)	.043 (.01)*	.003 (.01)	-.015 (.009)*	.002 (.003)	-.002 (.007)	-.0004 (.005)
Breed	-.025 (.014)*	.019 (.009)*	-.011 (.014)	.012 (.007)	-.024 (.012)*	.018 (.012)	-.004 (.012)	-.007 (.011)	.01 (.004)*	-.03 (.008)*	-.005 (.006)
Age	.0007 (.002)	.004 (.002)*	.008 (.002)*	-.0009 (.001)	-.01 (.002)*	.0001 (.002)	.008 (.002)*	-.006 (.002)*	-.0006 (.0006)	.003 (.001)*	.0002 (.0009)
Feed Type	-.024 (.009)*	-.005 (.006)	.036 (.008)*	.0009 (.005)	.039 (.008)*	-.035 (.007)*	-.023 (.007)*	.021 (.007)*	.007 (.003)*	-.012 (.005)*	.011 (.004)*
Days Fed Grain	-.0003 (.0001)*	-.0008 (.0001)*	-.00002 (.00002)	.00007 (.00009)	-.0002 (.0002)	-.0004 (.0002)*	-.0003 (.0001)*	.0005 (.0001)	.00002 (.00005)	-.00003 (.0001)	-.0008 (.0007)
Carcass Weight	.0002 (.0001)*	-.00007 (.00004)	-.00004 (.00007)	-.00003 (.00004)	.0002 (.0006)*	-.0002 (.0006)*	-.0001 (.00006)*	-.00007 (.00005)	.00004 (.00002)*	.0001 (.00004)*	-.00001 (.00003)
USDA Grade	.02 (.011)*	.0006 (.007)	.009 (.01)	.003 (.006)	.027 (.009)*	-.014 (.009)	-.003 (.009)	.011 (.008)	.0001 (.003)	.014 (.006)*	-.003 (.005)
Organic Label	.059 (.018)*	.002 (.011)	.003 (.017)	-.002 (.009)	-.016 (.015)	-.018 (.014)	-.021 (.014)	-.032 (.013)*	.011 (.005)*	-.012 (.01)	.008 (.007)
R^2	0.60	0.42	0.53	0.27	0.65	0.56	0.48	0.54	0.34	0.44	0.66

[a]*Denotes that the variable is significant at the .10 level. Standard errors are in parentheses.