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Performance of Alternative Component Pricing Systems for Pork

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ABSTRACT

One method of implementing value-based marketing is a component pricing system. This research develops and evaluates alternative component pricing systems for pork. Two electronic technologies for estimating carcass components (optical probe and electromagnetic scanner) were evaluated on two sets of data representing different populations. Model accuracy increased as additional components were added.

Key Words: carcass merit, component pricing, electromagnetic scanning, pork.

Much progress has been made in developing carcass merit pricing systems for pork. Research in the 1980s suggested adoption of carcass merit pricing was limited by lack of an objective measure of carcass leanness and quality [U.S. Department of Agriculture (USDA) 1984; Hayenga et al.; National Pork Producers Council 1987]. Objective measures of carcass leanness are now available due to improvements in technology including optical probes and ultrasound scanners which measure backfat depth and loin muscle depth, and electromagnetic scanners which measure the lean and fat tissue in the carcass.

In a typical carcass merit pricing program, the value of an individual carcass is determined by adjusting a base price for a carcass with a specified percentage of lean. Individual carcass value is then adjusted up or down based on the percentage of lean estimated by either the optical probe or steel ruler techniques. With regard to carcass evaluation technologies, Boland reported that the optical probe and steel ruler were the most widely used, with approximately 80% of all pork carcasses being evaluated using one of these technologies in 1997.

Moreover, Lawrence found that discounts for carcass weights outside the plant's desired weight range are typically an important part of the pricing systems. While these carcass merit systems, known as grid systems, are an improvement over live weight pricing, considerable debate continues over the magnitude of

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the premiums and discounts (Kenyon, McKissick, and Zering). In 1988, Kauffman et al. found that only 28% of all producers sold animals with some form of price discrimination for leanness, while Boland reported that this figure had risen to 78% in 1997. Over the same period, discounts for fat animals increased. Kauffman reported that fat discounts for producers selling hogs on carcass merit systems progressively increased from $0.06/cwt per 0.1 inch of backfat in 1984, to $0.85 per 0.1 inch of backfat in 1990. The same study, however, also noted that the 1990 figure for U.S. plants ($0.85/cwt) was approximately one-half the discount for backfat in Danish and Canadian pork marketing systems. Boland's 1997 survey suggests that this figure is now over $1. Furthermore, as suggested by the USDA (1984) and the National Pork Producers Council (1994), producers may have difficulty understanding carcass merit systems. Such carcass weight and backfat depth grids focus on "premiums" and "discounts" from a base carcass value. Fear of having their hogs discounted was listed by the Packers and Stockyards Administration as one reason producers dislike current carcass merit pricing systems (USDA 1984).

Following these developments closely, the National Pork Producers Council (NPPC), through its Lean Value Task Force, has expressed concern that current carcass merit systems are not adequate in conveying consumer preferences back to the producer because of the emphasis on premiums and discounts. In response, the NPPC requested a system for pricing animals based on "pounds of quality lean." This study evaluates the performance of a value-based marketing system in the form of component pricing developed in response to this request. The objectives of our investigation are to: (*a*) determine the appropriate components which should be included in the system, (*b*) develop a method to determine the prices for the components, and (*c*) measure the accuracy of the component pricing systems relative to live weight pricing and to the actual value of the carcass. Two models are considered, one using three components (total lean, total fat, and byproducts) and the other using six components (ham lean, loin lean, shoulder lean, other remaining lean, fat, and byproducts).

A component pricing system assesses total carcass value as comprised of the individual carcass components of lean, fat, and byproducts. Electronic technologies can be used to objectively estimate each of these components. The final carcass value is the sum of the value of the individual carcass components. A component pricing system offers several advantages over the grid systems currently used by many packers. Empirical work based on Kahneman and Tversky's prospect theory suggests that the disutility of giving something up is about twice as great as the utility of acquiring it (Benartzi and Thaler). The proposed component system would overcome the negative aspect of giving something up in "discounts," since even fat could have a positive price. A component pricing system can convey the same pricing signals as a grid with fewer numbers, and thus could be more easily understood by producers.

Component Pricing Theory

Component pricing models for milk have been studied by economists and dairy scientists, and have been widely adopted by the dairy industry (Perrin; Lesser; Lenz, Mittelhammer, and Hillers; Gillmeister et al.). In addition, both Perrin and Updaw analyzed protein and oil components in soybeans. Other commodities may be priced using component models in the future. Barry's observation of a future increase in the production of "identity-preserved" grains and oilseeds suggests that component pricing eventually may be adopted for these commodities.

Perrin's theoretical framework assumes that a commodity can be divided into its component parts, and "component prices" can be derived for these parts. Here, we adopt a more general framework since the products (hams, loins, etc.) a packer sells are not the same as the components (fat, lean, etc.) which can be measured. Define x as the m-vector of components and w as the m-vector of prices the producer is paid for each component. Similarly, define y as the n-vector of products and p as the net prices received for each product. The net prices are net of costs allocated to producing a given product and include a normal return. Let $y = f(x)$ describe the product transformation function which converts a carcass with components x into products. Under perfect competition, profit will be zero and marginal revenue will equal marginal cost:

$$(1) \quad p'\frac{\partial f(x)}{\partial x} = w'.$$

Thus, the component prices paid to producers (w) can be calculated directly given p and $\partial f(x)/\partial x$. Live weight pricing is the special case when w and x are scalars.[1]

Component Pricing of Pork

For a component pricing system to be successful, the components must be easily measurable, the proportion of the components must vary across carcasses, and the prices of the components must differ. The primary aggregated components of a pork carcass—lean and fat—clearly meet these criteria. The percentage of lean in a pork carcass varies substantially across carcasses primarily due to genotype and sex, as reported by Boland et al. (1995b). Lean obviously is worth more than fat, but the magnitude of the differential has been debated (Kauffman). While lean and fat are the most important components, the system also must account for the value of byproducts such as variety meats, bone, skin, and offal. One possible component system consists of a lean component, a fat component, and a byproduct component. However, plants receive prices based on the weight of the products of the disassembled pork carcass (such as loins, hams, jowls, trimmings, etc.) rather than the component (such as loin lean, ham lean, etc.). Note that each marketable product of the carcass consists of lean and fat, as well as bone and skin that are considered byproducts.

The measure of lean used in this study is dissected lean, which is the lean remaining when all trimmable fat, including seam fat, has been removed. Thus, marbling is included as part of the dissected lean. The alternative to dissected lean is fat standardized lean or lean that has been chemically analyzed and adjusted to some standard level of fat, typically 5% or 10% fat. The byproduct component is the residual, which includes all parts of the animal that are not lean or fat.

A system with lean, fat, and byproducts as components is attractive because it is simpler than a system with more components. However, a disaggregated system which separates lean into more components might value carcasses more accurately. The three most valuable products of the pork carcass are the ham, loin, and shoulder. Pricing the ham, loin, and shoulder lean as separate components will increase pricing accuracy only if the amount of lean in these products can be measured with existing technologies.

While the increased accuracy of this disaggregated system has advantages, Thompson noted that previous use of such a system by Hormel Foods in the mid-1930s was unsuccessful because it reduced plant line speeds. However, technological changes may make a disaggregated model practical in modern plants. Berg, Forrest, and Fisher found that electromagnetic scanning can accurately estimate percentage of ham lean, loin lean, and shoulder lean. Jekanowski et al. reported that electromagnetic scanning also can estimate percentage of lean in pork carcasses from animals fed porcine somatotropin (pST), a compound which increases the percentage of lean in hams and loins. Accurate estimates of the quantities of these components in individual carcasses are required to implement a component pricing system.

Measurement of Pork Components

This study used the Destron optical probe and electromagnetic scanner (Total Body Electrical

[1] Note that we do not let the product prices be a function of the components. Thus, our model is a simplification of the real world. Lean bellies are too thin and are actually worth less than regular bellies. A plant that consistently produced untrimmed butts and picnics which were leaner than average might be able to receive a premium. Our model does not consider these possibilities, but it could do so if we let p be a function of x.

Conductivity, commonly called TOBEC®) to estimate carcass composition.[2] Measurements of backfat depth and loin muscle depth are combined with carcass weight in a regression equation to estimate percentage of carcass lean:

$$(2) \quad \mathit{Total\ Lean} = \beta_0 + \beta_1 \mathit{Weight} + \beta_2 \mathit{Backfat} + \beta_3 \mathit{Loin\ Muscle} + \epsilon,$$

where *Total Lean* is total dissected lean as a percentage of carcass weight, *Weight* is hot carcass weight, *Backfat* and *Loin Muscle* are the respective backfat and loin muscle depths as measured by the Destron optical probe at the juncture of the third- and fourth-from-the-last rib 6 cm off the carcass midline, and ϵ is the error term. Percentage of lean rather than actual quantity of lean is used as the dependent variable because Jekanowski (pp. 117–20) has shown that this figure yields smaller standard errors when evaluated out of sample. Note that the quantity of lean is estimated by multiplying the prediction from (2) by carcass weight.

The regression equation for predicting percentage of carcass fat using the Destron optical probe is the same as (2) except that *Loin Muscle* is not included. Finally, the regression equation for estimating *Total Lean* as a percentage of carcass weight using electromagnetic scanning includes the variables *Weight*; *Temp,* which is carcass temperature measured as °F; *Leng,* which is carcass length measured in inches; and *H100,* which is the highest impedance reading from the electromagnetic scanner.[3]

[2] Electromagnetic scanning measures differences in electrical conductivity between fat and lean. Using this technology, a pork carcass is pulled on a belt through a scanning chamber containing an electromagnetic field. Measures of the resistance of the carcass to this magnetic field are taken. Because of the electrolytes and water present in fat tissue, fat mass impedes the magnetic field's flow. Conversely, lean tissue contains few electrolytes that would impede the flow of the field, and therefore lean has little effect on the impedance reading. Berg, Forrest, and Fisher provide a detailed explanation of the electromagnetic scanning technology.

[3] Carcass temperature is included as an explanatory variable because carcass conductivity varies with temperature, and laboratory conditions do not allow scanning of carcasses at constant intervals after slaughter as would be the case in a plant. Akridge et al. reported that carcass length does affect the scanning reading and could be measured in an industrial setting.

Four different lean components (ham, loin, shoulder, and other lean) are estimated by regressing the percentage of carcass lean in each of these cuts on similar variables. Ham lean is estimated as:

$$(3) \quad \mathit{Ham\ Lean} = \beta_0 + \beta_1 \mathit{Weight} + \beta_2 \mathit{Temp} + \beta_3 \mathit{Leng} + \beta_4 \mathit{H2045} + \beta_5 \mathit{H1070} + \epsilon,$$

where *H2045* and *H1070* are electromagnetic scanning measures at different points of impedance. When loin lean is in the electromagnetic scanner's chamber, the ham and belly are also partially present. Consequently, estimates of loin lean are less accurate than those for ham lean. Loin lean is estimated in the same manner as (3) except that a single scanning measure (*H60*) is used instead of *H1070* or *H2045.* Shoulder lean (which is comprised of the lean in the butts and picnics) and other lean (net of lean in the ham, loin, and shoulder) are measured using the same variables as the loin lean equation.

Several models were tested for both the optical probe and the electromagnetic scanner in the estimation of byproducts as a percentage of carcass weight. Carcass weight was the only variable significant in the regression equations. Therefore, pricing models for both technologies used the same regression equation to estimate the weight of the byproducts:

$$(4) \quad \mathit{Byproducts} = \beta_0 + \beta_1 \mathit{Weight} + \epsilon.$$

Prices for the Pork Components

A component pricing system must be based on market values for the components. However, as indicated earlier, designing a component pricing system for pork is more difficult than for milk or soybeans. For soybeans, prices for the two components (oil and meal) exist. But prices for lean do not exist, and all lean is not valued equally. To address this problem, the proposed system as defined in (1) uses prices for lean and fat which are weighted averages of the slaughter plant's expected prices for the products of the disassembled pork carcass (loins, hams, jowls, etc.). Thus, the plant's prices must be weighted by the proportion of the component in the product of the disassembled pork carcass. An advantage of this approach is that the system can be modified easily if the relationship between the TOBEC® measurements and carcass composition changes due to known genetics, porcine somatotropin, or management factors.

To determine component prices, a spreadsheet model was developed by Whipker, Akridge, and Jekanowski which calculates a bid price for the aggregated lean, ham lean, loin lean, shoulder lean, other lean, fat, and byproduct components. The spreadsheet converts percentage of lean into quantities using the regression equations depending upon the number of components in the model and determines bid prices to solve (1). The bid price is calculated given: (*a*) a specific carcass utilization scheme used by a slaughter plant, (*b*) a set of prices the plant manager expects to realize for the pork cuts and products marketed, (*c*) the costs of slaughter and processing for each cut and product, and (*d*) a target return for each carcass. If animals are acquired for the bid model prices that reflect the products being sold, the projected return or margin would be realized.

Utilization of the carcass by the pork slaughter plant has an important impact on the component prices. Pork cuts sold in lean, boneless form would result in a relatively high price for the lean component and a relatively low price for the fat component, since the fat trimmed away is used for rendering or other purposes. On the other hand, if the entire carcass is sold in trimmed wholesale form, the differential between the fat and lean component prices will diminish, as a relatively large amount of fat is marketed at the price of the trimmed wholesale cut products. Therefore, the prices of the lean, fat, and byproduct components depend directly on the plant's utilization of the carcass. Note that the plant's utilization potentially could change daily, depending upon whether the pork cuts are being sold to the export, food service, or retail industries. The bid price for any individual component in the disaggregated model is calculated in a similar manner. The per pound price for the byproduct component is again a weighted average of the values of the individual products. Most of the prices for these products (heart, kidney, tongues, etc.) are reported by the USDA. Because they have a relatively low weight and price, byproducts may not be important to total value.

Proposed Pricing Used in System Evaluation

The component pricing systems were evaluated based on their ability to estimate accurately the value of pork carcasses of known composition and value. Two studies providing complete dissection data on every carcass component were available: Kuei (212 animals) and Thompson et al. (136 animals). A random subset of 64 animals from the Kuei data (referred to as "same population" data) is set aside for out-of-sample validation of the regression equations which are estimated from the remaining 148 animals. The 136 animals from the entirely separate Thompson et al. data also are used for validation purposes (referred to here as "different population" data). Table 1 presents summary statistics for both sets of data.

To provide a set of base (actual or true) values, the carcasses were valued using average 1995 USDA (commonly called "Blue Sheet") prices. These prices then were adjusted by adding overages reflecting a closely trimmed product with no bone remaining. These overages represent premiums over the USDA prices that a slaughter plant in Indiana typically obtains for the primal cut products of the disassembled pork carcass when sold on a lean, boneless basis. Values for hams and loins reflect a fat-free product.

When possible, these products were valued by weight and price class for each individual carcass. The USDA reports prices for the primal cut products in different weight categories while reporting only one price (per pound) for many of the byproducts. The butts, picnics, bellies, and spareribs were valued by multiplying each individual weight-class price by the primal cut weight. Other products, such as

Table 1. Mean, Standard Deviation, and Range for Selected Variables from the Same Population and Different Population Data Sets

Variable	Mean	Std. Dev.	Min.	Max.
Same Population Data (n = 212):[a]				
Warm carcass weight (lbs.)	180.20	18.70	147.00	229.5
Backfat depth, 3rd/4th-from-last rib (inches)	.95	.20	.60	1.7
Dissected lean (%)	49.40	3.90	38.70	61.7
Dissected ham lean (%)	14.40	1.12	10.70	18.6
Dissected loin lean (%)	12.10	1.20	8.40	15.5
Dissected shoulder lean (%)	8.90	.41	4.10	12.6
Dissected fat (%)	31.50	4.70	17.20	44.3
Different Population Data (n = 136):[b]				
Warm carcass weight (lbs.)	190.20	32.09	126.00	264.0
Backfat depth, 3rd/4th-from-last rib (inches)	1.08	.31	.47	2.1
Dissected lean (%)	49.26	3.66	41.34	58.6
Dissected ham lean (%)	14.70	2.52	8.55	23.2
Dissected loin lean (%)	12.12	2.12	7.46	19.2
Dissected shoulder lean (%)	9.12	.66	4.51	7.5
Dissected fat (%)	32.96	8.70	23.16	68.3

[a] Kuei.
[b] Thompson et al.

lean trim and byproducts, were valued by multiplying the weight of each product by the 1995 (adjusted) USDA price. A fixed cost of $13.43 was subtracted from each carcass for slaughter and trimming costs and a profit goal.[4] In addition, a bone removal cost for hams and loins of $0.05 and $0.10 per pound, respectively, of total primal cut weight was deducted (Boland, Foster, and Akridge). Resulting prices for the components are shown in table 2. The table 2 figures also reflect premiums and discounts on percentage of lean, and a discount if the animal's warm carcass weight lies outside the plant's preferred buying range of 170 to 195 pounds. These premiums and discounts were added to the value of each carcass. For the three-component models, both the electromagnetic scanner and the Destron optical probe were used to estimate the quantities of the components. Only the electromagnetic scanner is considered for separating ham lean, loin lean, shoulder lean, and the other remaining lean into separate components (the six-component model). Finally, to examine the impact of byproduct value, the three-component models are modified to consider byproduct value to be a fixed constant per animal. Consequently, this will be a two-component model (lean and fat) with a fixed byproduct value constant.

[4] This figure has been multiplied by a constant to disguise the plant's identity. However, this figure is near those reported by DiPietrie, Morehead, and Duffy.

Evaluation of Alternative Systems

The systems were evaluated out of sample using the 64 animals from the "same population" data and the 136 animals from the "different population" data. The estimated value of each pork carcass is calculated for each sample. In addition to the estimated component weights obtained from the electronic technologies, actual component weights from dissection data were used in valuing the carcasses. This allows separating the total error in estimating carcass value into the error from inaccurate estimation of the component weights and the error due to aggregating the components.

Previous results from Akridge et al., and Boland et al. (1995a) reported no significant differences (using nonnested *J*-tests) between using the electromagnetic scanner and the op-

Table 2. Weights, Revenues, Costs, Values, and Prices of Carcass Components for a Representative Animal for the Three- and Six-Component Models

Model	Weight (lbs.)	Revenue ($/hog)	Cost[a] ($/hog)	Total ($/hog)	Price ($/cwt)
Three-Component:					
Lean	83.2	86.08	5.35	80.73	97.00
Fat	56.8	20.05	3.65	16.40	28.88
Byproducts	90.4	17.12	5.81	11.32	12.52
Total	230.4	123.25	14.80	108.45	
Six-Component:					
Ham lean	23.2	22.49	1.49	21.00	90.38
Loin lean	19.7	43.75	1.27	42.49	215.33
Shoulder lean	18.7	11.90	1.20	10.69	57.15
Other lean	21.6	7.94	1.38	6.55	30.41
Fat	56.8	20.05	3.65	16.40	28.88
Byproducts	90.4	17.12	5.81	11.32	12.52
Total	230.4	123.25	14.80	108.45	

Notes: The two-component model uses the same prices for lean and fat, but has a byproduct credit value of $11.32. Numbers may not sum to totals in table because of rounding errors.

[a] These cost figures have been disguised to protect the identity of the cooperating pork slaughter plant, but are similar to DiPietrie, Morehead, and Duffy's figures.

tical probe to estimate carcass value per cwt using in-sample data. Both of these studies also reported that a combination of these two technologies was significantly better in estimating value (using nested tests). However, a combination of technologies may be impractical for a slaughter plant in an industrial environment. In order to determine if the optical probe or the electromagnetic scanner estimated significantly better in the two out-of-sample sets of data for the two- and three-component models, the out-of-sample mean square errors of each equation are tested against one another using Ashley, Granger, and Schmalensee's (AGS) test following the procedures described by Brandt and Bessler.

Two types of noncomponent pricing were considered to provide benchmark comparisons. First, all hogs were assumed sold at the same price per pound of live weight (a one-component model). Live pricing was based on average 1995 prices of the Indiana-Ohio direct, as this is the market used by the cooperating plant in this study. Second, the USDA's lean value grid pricing was used as another measure. The animals were sorted into percentage of lean and carcass weight categories. If the weight or percentage of lean was outside the USDA's range of categories (i.e., less than 140 pounds and 41% of lean, or greater than 222 pounds and 60% of lean), the nearest price per pound of carcass weight was used.

An F-test is used to test the hypothesis that the RMSEs between actual and predicted values are equal between one pricing method versus another pricing method (Steel and Torrie, p. 83). The results of these paired tests, which are conducted on both sets of data, will enable us to determine whether one pricing method performs significantly differently than another.

Results

Estimated parameters of the ordinary least squares regression equations are presented in tables 3 and 4. The electromagnetic scanner is more accurate than the optical probe in estimating percentage of aggregated lean, while the optical probe is more accurate in estimating percentage of fat. The electromagnetic scanner is more accurate in estimating ham lean than loin lean and shoulder lean, as expected. The regression equation for byproducts has low explanatory power.

Table 3. Parameters, Standard Errors, and Out-of-Sample Statistics for Estimating Percentage of Lean Using an Optical Probe and an Electromagnetic (EM) Scanner

		Electromagnetic Scanner				
Variable	Probe % Lean	% Lean	% Ham	% Loin	% Shoulder	% Other
Intercept	64.439	84.419	28.163	17.562	2.872	38.280
Warm carcass *Weight*	−.025*	−.241*	.073*	.053*	.028*	−.110*
(lbs.)	(.01)	(.013)	(.004)	(.005)	(.004)	(.002)
Carcass *Leng* (inches)		.324*	.043*	.103*	−.043*	.139*
		(.054)	(.016)	(.021)	(.011)	(.05)
Carcass *Temp* (°F)		−.92*	−.287*	−.203*	−.035*	−.379*
		(.18)	(.033)	(.043)	(.001)	(.056)
EM Measures:						
H100		.179*				
		(.009)				
H60				.065*	.006*	.079*
				(.006)	(.001)	(.005)
H2045			.262*			
			(.018)			
H1070			.005*			
			(.0008)			
Probe Measures:						
Backfat depth	−9.172*					
	(.753)					
Loin Muscle depth	.747					
	(.628)					
R^2	.500	.655	.731	.401	.356	.587
Same/Different Population Data:						
Squared correlation of actual and predicted	.85/.53	.83/.51	.81/.37	.82/.42	.85/.36	.80/.48
RMSE (%)	2.8/3.2	2.3/4.0	.80/2.1	.90/2.5	1.0/1.1	1.3/4.9

Sources: Mauney; Kuei.
Notes: Single asterisk (*) denotes the variable is statistically significant at the .05 level. Values in parentheses are standard errors.

However, the mean squared errors of the equations for estimating percentage of aggregated lean and fat for the optical probe and electromagnetic scanner were not significantly different from one another when evaluated using AGS's test. The *F*-statistics were 13.43 and 14.77 for the "same population" data and 21.37 and 24.77 for the "different population" data, respectively. This result suggests that neither model is preferred over the other, and either equation can be used to estimate percentage of aggregated lean or fat. This finding is consistent with the nonnested test results from the Akridge et al. and the Boland et al. (1995a) studies. The correlation between actual and predicted values for both sets of out-of-sample data were lower for estimating percentage of lean components relative to the percentage of fat.

Differences in RMSE between the actual value per hog as measured by the different pricing models and the dissected quantities for both sets of data ("same population" and "different population") are contained in table 5. Live weight pricing is denoted as LIVE; USDA lean value grid is denoted by CAR-

Table 4. Parameters, Standard Errors, and Out-of-Sample Statistics for Estimating Percentage of Fat Using an Optical Probe and an Electromagnetic (EM) Scanner

Variables	Probe % Fat	Electromagnetic Scanner % Fat	Electromagnetic Scanner % Byproducts
Intercept	8.602	−7.68	47.38
Hot carcass *Weight* (lbs.)	.035*	.28*	−.061*
	(.01)	(.017)	(.01)
Carcass *Leng* (inches)		−.449*	
		(.072)	
Carcass *Temp* (°F)		1.06*	
		(.143)	
EM Measure: *H100*		−.186*	
		(.013)	
Probe Measure: *Backfat* depth	12.77*		
	(.73)		
R^2	.641	.583	.206
Same/Different Population Data:			
Squared correlation of actual and predicted	.82/.71	.78/.60	.69/.40
RMSE	3.011	2.875	2.412

Sources: Mauney; Kuei.
Notes: Single asterisk (*) denotes the variable is statistically significant at the .05 level. Values in parentheses are standard errors.

CASS; two-component pricing (lean, fat, and a constant byproduct value) with the optical probe is denoted as PR2; three-component pricing (lean, fat, and byproducts measured per pound) with the optical probe is denoted as PR3; two- (three-, six-) component pricing with the electromagnetic scanner is denoted as EM2 (EM3, EM6); and two- (six-) component pricing using actual dissected quantities is denoted as DI2 (DI6).

For both sets of data, there were significant differences between live weight pricing (LIVE) and the other pricing models. This result suggests that the component pricing models and USDA's lean value grid (CARCASS) have higher accuracy than the LIVE pricing model. In particular, LIVE has the highest variability in prediction. This may explain why plants have moved away from live weight pricing in the 1990s. There were no significant differences between the two- (EM2 and PR2) and three- (EM3 and PR3) component pricing models, and CARCASS, suggesting no differences between USDA's lean value grid and pricing lean and fat components with a fixed byproduct value per head or a variable price per pound. A fine enough grid should be able to give exactly the same prices as a component system. The USDA grid has a slightly higher RMSE. It could be higher due to being based on slightly different prices, or to the rounding error created by the grid.

The system using a fixed byproduct value per head (the two-component model where PR2 and EM2 denote the two-component pricing method for the optical probe and the electromagnetic scanner, respectively) had no significant differences from the system employing byproduct pricing on a per pound basis (the three-component model where PR3 and EM3 denote the three-component pricing method for the optical probe and the electromagnetic scanner, respectively). Byproducts had little impact on pricing accuracy since their weight varies little across hogs and they have relatively low value. Given these results, either the electromagnetic scanner or the op-

Table 5. RMSEs ($/hog) Between Actual and Predicted Values for Alternative Pricing Methods for the Same Population and Different Population Data Sets

Pricing Method[a]	RMSE Same Pop.	RMSE Different Pop.	LIVE	CARCASS	PR2	PR3	EM2	EM3	EM6	DI2	DI6
LIVE	6.33	7.01	.	(d,d)[b]	(d,d)	(d,d)	(d,d)	(d,d)	(d,d)	(d,d)	(d,d)
CARCASS	4.91	5.74	.	.	(n,n)	(n,n)	(n,n)	(n,n)	(d,d)	(d,d)	(d,d)
PR2	4.78	5.57	.	.	.	(n,n)	(n,n)	(n,n)	(n,d)	(d,d)	(d,d)
PR3	4.52	5.20	.	.	.	.	(n,n)	(n,n)	(n,n)	(d,d)	(d,d)
EM2	4.15	5.11	.	.	.	.	.	(n,n)	(n,n)	(d,d)	(d,d)
EM3	4.02	4.71	.	.	.	.	.	.	(n,n)	(d,d)	(d,d)
EM6	3.82	4.17	.	.	.	.	.	.	.	(d,d)	(d,d)
DI2	2.67	2.90	.	.	.	.	.	.	.	.	(d,d)
DI6	1.51	2.25	.	.	.	.	.	.	.	.	.

[a] Pricing method acronyms are defined as follows: LIVE is live weight pricing; CARCASS is the USDA lean value grid pricing; PR2 is two-component (lean and fat, with a constant byproduct value) pricing using an optical probe; PR3 is three-component (lean, fat, and byproducts measured per pound) pricing using an optical probe; EM2 is two-component pricing using an electromagnetic scanner; EM3 is three-component pricing using an electromagnetic scanner; EM6 is six-component (ham lean, loin lean, should lean, other lean, fat, and byproducts) pricing using an electromagnetic scanner; DI2 is two-component pricing using actual dissected quantities of components; and DI6 is six-component pricing using actual dissected quantities of components.

[b] The letters in parentheses represent *F*-test results on (same population data, different population data). An "n" denotes no difference between RMSEs being measured based on the *F*-test, while a "d" denotes a significant difference between RMSEs based on the *F*-test. All tests were conducted at the .05 level of significance. For example, the same (different) population RMSE for the two-component optical probe model, PR2 (RMSE = $4.78 and $5.57, respectively) is not statistically different from the same population RMSE for EM6 (RMSE = $3.82) at the .05 level of significance, but is statistically different from the different population data (RMSE = $4.17). Thus, in this example, (n,d) denotes no difference and different, respectively.

tical probe could be used with the two- and three-component models.

Significant differences in predicting value were found when testing the six-component model using an electromagnetic scanner (EM6) against the component pricing models using an optical probe (PR2 and PR3), suggesting that a disaggregated pricing model is more accurate. However, no significant differences were found when comparing the component pricing models using an electromagnetic scanner (EM2, EM3, and EM6). This suggests that a plant with an electromagnetic scanner could use any of these three-component pricing models for prediction.

Focusing on the relative accuracy issue, as expected, significant differences in value were found when comparing the actual dissected components (DI2 and DI6) with all other pricing models. However, this method is infeasible given the cost and tedious tasks associated with dissection. Finally, given the similar results between data sets, this suggests that the technologies when used with a component model may be relatively accurate over different animal populations.

Summary

This research evaluated alternative component pricing models which provide a value-based system based on "pounds of lean." A component pricing system has a positive price for every component and does not offer the psychological disadvantage of the discounts used with a live weight or grid pricing system. The component pricing system is more flexible than a fixed grid and can respond easily to changes in market prices for the components. It also could be consistent across slaughter plants, making it easier for producers to compare bids for their animals.

Component pricing models are clearly more accurate than live weight pricing. Values derived with the USDA lean value grid were not significantly less accurate than a two- or three-component model, as expected. Adding more components improves the accuracy of the component model. Additional research is needed to determine if the value of the more accurate estimate exceeds the cost of making the estimate and outweighs the additional complexity of the model.

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