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ARTICLE

Multiple Regression Analysis to Estimate the Unit Price of Hanwoo (*Bos taurus coreanae*) Beef

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Abstract

This study were estimated the contribution of carcass traits to unit price, to analyze the marbling score as a categorical variable rather than a numerical variable, and to develop an optimal model that also includes the holiday effect and the raising period. The data for this study were acquired from the Quality Evaluation of the Korea Institute for Animal Products, and consisted of the trading records of 1,613,699 heads at 12 wholesale markets from 2010 to 2014. The unit price of a cow was estimated from the following parameters: -52.50 Won/mm, 8.93 Won/cm^2, 7.20 Won/kg, and -1.04 Won/day for backfat thickness, eye muscle area, carcass weight, and raising period, respectively. Parameters for the dummy variables of marbling scores varied from 0 to 8328.74 Won/kg, which means that each marbling score grade had a different price value. The unit price of a steer was estimated from the following parameters: -92.12 Won/mm, 20.22 Won/cm^2, 1.30 Won/kg, and -1.72 Won/day for backfat thickness, eye muscle area, carcass weights, and raising period, respectively. Parameters for dummy variables of marbling scores varied from 0 to 7338.80 Won/kg, which means that the grades of each marbling score had different price values. The unit price of sales during traditional holidays was significantly higher (827.71 Won/kg for cows, and 645.15 Won/kg for steers) than during non-holidays.We conclude that the use of categorical values for marbling scores would be needed to evaluate the price of Hanwoo beef using multiple regression analysis based on carcass traits and environmental factors.

Keywords dummy variable, Hanwoo, marbling score, multiple regression, unit price

Introduction

Contribution analysis of the unit price is important, because the unit price of Hanwoo beef directly correlates with farmer income. The exact contribution analysis of factors towards the unit price enhances farmer income through decreases in production cost and improvement in the efficiency of breeding plans. Thus, estimation of the unit price and the effect of genetic parameters on carcass traits have been studied; examples include the contribution analysis of carcass traits towards the unit price of Hanwoo beef (Park *et al.,* 2015; Sun *et al.,* 2012), and the estimation of the effect of genetic parameters on carcass traits (Koo *et al.,* 2011; Sun *et al.,* 2010; Utama *et al*., 2017; Yoon *et al.,* 2002). The contribution analysis of carcass traits towards unit price in Hanwoo beef is important because farmers can uti-

lize the results to improve planning.

Multiple regression analysis, with unit price as dependent variable and carcass traits as independent variable, is used for the contribution analysis of carcass traits. Existing research methods have studied numerical variables for backfat thickness, eye muscle area, carcass weight, and marbling score (Kim *et al.,* 2015; Kong *et al.,* 2014; Sun *et al,.* 2012). However, the marbling score was set as grades one to nine; treating the marbling score as a categorical variable rather than a numerical variable is therefore more appropriate for contribution analysis. The objectives of this study were to estimate the contribution of carcass traits to unit price to analyze the marbling score as a categorical rather than a numerical variable, and to develop an optimal model that also includes the holiday effect and the raising period.

Materials and Methods

Data

The data for this study were acquired from Korea Institute for Animal Products Quality Evaluation. The data consisted of trading records of 1,613,699 heads (Steer heads: 956,276; cow heads: 657,423) at 12 wholesale markets from 2010 to 2014. Table 1 represents the number of records by sex and auction price.

Statistical analysis methods

1. Contribution analysis of factors

The main factors affecting the unit price of Hanwoo beef are carcass traits (backfat thickness, eye muscle area, carcass weights, and marbling scores) and environmental factors such as selling time and raising period. This study used multiple linear regression analysis to analyze the contribution of each factor.

Model 1:

$$Y = a + b_1\,BF + b_2\,EMA + b_3\,CW + b_4\,MS + e$$

Model 2:

$$Y = a + b_1\,BF + b_2\,EMA + b_3\,CW + b_4\,MS + b_5\,RP + e$$

Y: Unit price (Won/kg)
BF: Backfat thickness (mm)
EMA: Eye muscle area (cm^2)
CW: Carcass weight (kg)
MS: Marbling score
RP: Raising period (d)
e: residual error

Thus, the dependent variable Y is the unit price; the carcass traits (backfat thickness, eye muscle area, carcass weights, and marbling scores) are the dependent variables; b_1, b_2, b_3, b_4, and b_5 are the regression coefficients of each trait; and *e* is the residual error. In order to compare the contributions of the variables, the ordinarily used squared semi-partial correlation was used for this study. This method does not only consider the effect of other independent variables, but also indicates the relative contribution in the regression analysis model.

2. Contribution analysis of factors using dummy variables

The marbling score was treated as a categorical value in this model by using a dummy variable.

Model 3:

$$Y = a + b_1\,BF + b_2\,EMA + b_3\,CW + b_4\,MS\_dum_i + e$$

Model 4:

$$Y = a + b_1\,BF + b_2\,EMA + b_3\,CW + b_4\,MS\_dum_i + b_5\,HD + b_6\,RP + e$$

Y: Unit price for dependent variable
BF: Backfat thickness
EMA: Eye muscle area
CW: Carcass weight
MS: Marbling score
MS_dum_i: i grade marbling score (i = 2, 3, 4, 5, 6, 7, 8, 9)
HD: Holiday effect
RP: Raising period
e: residual error

The use of a dummy variable in the contribution analysis of the unit could be more accurate than the existing analysis method. When the marbling score is processed using numerical variables, differences between grades are

Table 1. Number of records of Hanwoo cattle by sex and auction price

Sex	Number of records	Auction price (Won)
Cows	657,423	12735.92±2,823.78
Steers	956,276	14707.14±2,339.91
Total / Average	1,613,699	13,721.54±2,581.85

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not visible. However, when the marbling score is processed using categorical variables, differences between grades are considered.

MS_dum_i refers to the difference in unit price between marbling score 1 and I; the MS_dum_i variable consists of 0 and 1. For example, if the marbling score is 2, the MS_dum_2 value is 1 and the other values are 0, indicating the difference in unit price between marbling scores 1 and 2. The holiday effect was used to estimate the effect of selling Hanwoo beef from 30 d before the Korean traditional holidays (e.g., New Year's Day, Thanksgiving). When the effect of the raising period was used as independent value, the analysis was separated by sex because of the significant difference in raising periods.

Results and Discussion

The main factors affecting the unit price of Hanwoo meat are carcass traits (backfat thickness, eye muscle area, carcass weights, and marbling scores) as well as environmental factors such as raising period and selling time (including effects of Korean traditional holidays such as New Year's Day and Thanksgiving). To our knowledge, marbling scores have been used as numerical variables in multiple regression analyses during several Korean studies. Therefore, we treated two factors (marbling scores and holiday effect) as categorical variables to investigate the effects of carcass traits and environmental factors on the unit price of meat more accurately.

Statistics of carcass traits

The averages and standard errors of the data are represented in Table 2. Backfat thickness, eye muscle area, carcass weight, marbling score, and auction price were 12.88 ±5.344 mm, 86.02±12.076 cm^2, 380.36±64.229 kg, 4.74± 2.046, and 13,904.06±2726.020 Won, respectively.

Considering the results of prior studies, Park *et al.* (2015) report that the averages of backfat thickness, eye muscle area, carcass weight, marbling score, and auction price were 13.73±5.30 mm, 81.76±12.73 cm^2, 360.24± 69.57 kg, 4.66±2.06, and 14,443.93±3649.83 Won, respectively. Koo *et al.* (2011) report that backfat thickness, eye muscle area, carcass weight, and marbling score were 11.39±5.40 mm, 81.79±12.21 cm^2, 362.30±67.15 kg, and 4.38±2.29, respectively. Choi *et al.* (2011) report backfat thickness, eye muscle area, carcass weight, and marbling scores of 10.30±4.62 mm, 81.34±9.55 cm^2, 361.76±50.10 kg, and 3.96±2.33. Bulls are excluded from this study, and results are therefore less than those of prior studies.

Contribution analysis of carcass traits

Table 3 represents the contribution analysis of carcass traits. Parameters to estimate the unit price of Hanwoo beef were -83.09 Won/mm, 11.51 Won/ cm^2, 5.30 Won/ kg, 918.00 Won/score for backfat thickness, eye muscle area, carcass weight, and marbling score, respectively. Squared semi-partial correlations to estimate the unit price of Hanwoo were 0.023, 0.001, 0.008, and 0.38 for backfat thickness, eye muscle area, carcass weight, and marbling score, respectively. The corresponding percentage values

Table 2. Simple statistics for carcass traits and auction price of Hanwoo beef

	n	Mean±SD	Max.	Min	Coefficient of variation (%)
Back fat thickness (mm)	1,613,699	12.88±5.344	40	1	41.49
Eye muscle area (cm^2)	1,613,699	86.02±12.076	196	40	14.04
Carcass weight (kg)	1,613,699	380.36±64.229	761	150	16.89
Marbling score (score)	1,613,699	4.74±2.046	9	1	43.14
Auction price (Won)	1,613,699	13,904.06±2,726.020	29999	8001	19.61

Table 3. Squared semi-partial regression coefficients of carcass traits on auction price

	Carcass traits	Parameter (won)	Squared semi-partial correlation	Contribution (%)
Auction Price	Back fat thickness	-83.09**	0.023	5.58
	Eye muscle area	11.51**	0.001	0.24
	Carcass weight	5.30**	0.008	1.94
	Marbling score	918.00**	0.380	92.23
	Intercept	7614.81**	R-square	0.57

R-square, Coefficient of determination for the multiple regression model.
**$p<0.01$.

of the squared semi-partial correlations were 5.58%, 0.24%, 1.94%, and 92.235%, respectively. Marbling score had the highest contribution. R-square was 0.57 in this model.

Park *et al.* (2015) report that the parameters of backfat thickness, eye muscle area, carcass weight, and marbling score to estimate the unit price of Hanwoo were -59.90 Won/mm, 18.71 Won/ cm^2, 3.06 Won/ kg and 1187.49 Won/score, respectively. In addition, the contributions of each trait were 3.08%, 0.83%, 0.66%, and 95.41%. Compared with this study, the Hanwoo beef unit price was more affected by marbling score in Gyeongsangnam-do than in the whole country. Choi *et al.* (2011) report that partial R-squares were 0.0004, 0.0000, 0.0035, and 0.3463 for backfat thickness, eye muscle area, carcass weight, and marbling score, respectively, and that backfat thickness and eye muscle area did not affect the unit price. That result was different in this study. The research of Sun *et al.* (2012) indicates that the marbling score effect was absolute high. The results of Sun *et al.* (2012) are similar to the results of this study.

Contribution analysis of factors by sex

Table 4 represents the contribution analysis of factors by sex. Parameters to estimate the unit price of a cow were -50.56 Won/mm, 8.78 Won/ cm^2, 6.76 Won/ kg, 1,058.65 Won/score, and -0.97 Won/day for backfat thickness, eye muscle area, carcass weight, marbling score, and raising period, respectively. The R-square of this model was 0.55. Parameters to estimate the unit price of a steer were -89.06 Won/mm, 19.43 Won/cm^2, 1.75 Won/kg, 80.89 Won/score, and -1.78 Won/day for backfat thickness, eye muscle area, carcass weight, marbling score, and raising period, respectively. The R-square was 0.54. Contributions for the cow were 1.50%, 0.21%, 1.29%, 89.89%, and 7.10% for backfat thickness, eye muscle area, carcass weight, marbling score, and raising period, respectively, and contributions for the steer were 0.23%, 1.17%, 7.73%, 89.93%, and 0.94% for backfat thickness, eye muscle area, carcass weight, marbling score, and raising period, respectively.

When analyzed by sex (Table 4), the parameter for marbling score of a cow was higher than in model 1, and the parameter for backfat thickness of a cow was lower than in model 1. In addition, the parameter for carcass weight of a steer was lower than in model 1; the parameter for the eye muscle area of a steer was higher than in model 1; and the parameter for raising period in a steer was higher than for a cow. When cows and steers were analyzed separately, a more accurate model was estimated.

Contribution analysis of carcass traits using dummy variables

Table 5 represents the contribution analysis of carcass traits using dummy variables. Parameters to estimate the unit price of Hanwoo beef were -86.71 Won/mm, 12.35 Won/cm^2, and 4.99 Won/kg for backfat thickness, eye muscle area, and carcass weight, respectively. Parameters for marbling score dummy variables were 1038.99, 1286.40, 3361.15, 3564.02, 4895.19, 5123.53, 6615.73, and 7336.12 Won/kg. The parameter for MS_dum_2 refers to the price difference between marbling score 1 and 2. In the case of MS_dum9, the difference in unit price between marbling score 1 and 9 was 7336.12 Won. The contribution of Hanwoo beef in model 1 was 4.79%, 0.38%, 1.34%, and 93.50% for backfat thickness, eye muscle area, carcass weight, and

Table 4. Squared semi-partial regression coefficients of carcass traits on auction price

	Carcass traits	Parameter (won)	Squared semi-partial correlation	Contribution (%)
Auction Price (only cow)	Back fat thickness	-50.56**	0.007	1.50
	Eye muscle area	8.78**	0.001	0.21
	Carcass weight	6.76**	0.006	1.29
	Marbling score	1,058.65**	0.418	89.89
	Raising period	-0.97**	0.033	7.10
	Intercept	7,861.34**	R-square	0.55
Auction Price (only steer)	Back fat thickness	-89.06**	0.001	0.23
	Eye muscle area	19.43**	0.005	1.17
	Carcass weight	1.75**	0.033	7.73
	Marbling score	808.89**	0.384	89.93
	Raising period	-1.78**	0.004	0.94
	Intercept	10,781**	R-square	0.54

R-square, Coefficient of determination for the multiple regression model.
**$p<0.01$.

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Table 5. Squared semi-partial regression coefficients of carcass traits on auction price[1)]

	Carcass traits	Parameter (won)	Squared semi-partial correlation	Contribution (%)
Auction Price	Back fat thickness	-86.71**	0.025	4.79
	Eye muscle area	12.35**	0.002	0.38
	Carcass weight	4.99**	0.007	1.34
	MS_dum2	1,038.99**	0.004	0.77
	MS_dum3	1,286.40**	0.006	1.15
	MS_dum4	3,361.15**	0.040	7.66
	MS_dum5	3,564.02**	0.043	8.24
	MS_dum6	4,895.19**	0.080	15.33
	MS_dum7	5,123.53**	0.080	15.33
	MS_dum8	6,615.73**	0.115	22.03
	MS_dum9	7,336.12**	0.120	22.99
	MS_dum_all		0.488	93.50
	Intercept	8,568.30**	R-square	0.5907

[1)]Squared semi partial regression coefficients of carcass traits on cow auction price was developed by using Model 3.
R-square, Coefficient of determination for the multiple regression model; MS_dum_all, Subtotal of MS_dum_i (i=2, 3, 4, 5, 6, 7, 8, 9).
**$p<0.01$.

marbling score, respectively. The R-square was 0.59.

When analyzing the marbling score with numerical variables, the price difference between the scores was fixed at 918.00 Won. However, when analyzing the marbling score as a categorical variable, we could see the detail unit price difference. According to this result, the method that used dummy variables was better than the one that used numerical variables. It seemed that the unit prices of grades 2-3, 4-5, 6-7, and 8-9 were similar because grades 2-3, 4-5, 6-7, and 8-9 are graded as a group in the animal products grading service.

Contribution analysis of factors using dummy variables by sex

Tables 6 and 7 represent the contribution analysis of factors using dummy variables by sex. The parameters to estimate the unit price of a cow were -52.50 Won/mm, 8.93 Won/ cm^2, 7.20 Won/kg, and -1.04 Won/day for backfat thickness, eye muscle area, carcass weight, and raising period, respectively. Parameters for dummy variables for marbling scores 1-9 were 0, 531.19, 703.84, 2947.24, 3271.88, 4858.43, 5232.94, 7397.39, and 8328.74 Won/kg, which means that each marbling score grade had differed price values. The price of beef sold during traditional holidays was significantly higher than that sold during a non-holiday at 827.71 Won/kg for a cow. The R-square was 0.59 in this study. The parameters used to estimate the unit price of a steer were -92.12 Won/mm, 20.22 Won/ cm^2, 1.30 Won/kg, and -1.72 Won/day for backfat thickness, eye muscle area, carcass weight, and raising period, respectively. Parameters for dummy variables for marbling scores 1-9 were 0, 1719.36, 1850.90, 3713.50, 3749.51, 4995.58, 5189.18, 6551.40, and 7338.80 Won/kg, which means that each marbling score grade had differed price values. The price of beef sold during traditional holidays was significantly higher than that sold during non-holidays at 645.15 Won/kg for a cow. The R-square was 0.58.

To obtain model 4 that was used in Tables 6 and 7, the effects of the holiday and raising period were added to model 3 (that was used for Table 5). Model 4 resulted in a lower contribution of marbling score and higher R-square than model 3. Therefore, model 4 of Tables 6 and 7 was more accurate than model 3 of Table 5.

Conclusion

Parameters to estimate the unit price of Hanwoo beef were -83.09 Won/mm, 11.51 Won/ cm^2, 5.30 Won/kg, 918.00 Won/score for backfat thickness, eye muscle area, carcass weight, and marbling score, respectively. Squared semi-partial correlations to estimate the unit price of Hanwoo were 0.023, 0.001, 0.008, and 0.38 for backfat thickness, eye muscle area, carcass weight, and marbling score, respectively. The corresponding percentage values of the squared semi-partial correlations were 5.58%, 0.24%, 1.94%, and 92.235%, respectively. Marbling score had the highest contribution. R-square was 0.57 in this study.

In conclusion, the multiple regression analysis of model 4 (that included carcass traits, raising period, and holiday effects) was the most accurate estimated contribution of

Table 6. Squared semi partial regression coefficients of carcass traits on cow auction price[1)]

	Carcass traits	Parameter (won)	Squared semi-partial correlation	Contribution (%)
Auction Price (only cow)	Back fat thickness	-52.50**	0.008	1.34
	Eye muscle area	8.93**	0.001	0.17
	Carcass weight	7.20**	0.007	1.18
	Raising period	-1.04**	0.037	6.22
	Holyday effect	827.71**	0.015	2.52
	MS_dum2	531.19**	0.002	0.34
	MS_dum3	703.84**	0.003	0.50
	MS_dum4	2947.24**	0.049	8.24
	MS_dum5	3271.88**	0.055	9.24
	MS_dum6	4858.43**	0.108	18.15
	MS_dum7	5232.94**	0.096	16.13
	MS_dum8	7397.39**	0.129	21.68
	MS_dum9	8328.74**	0.085	14.29
	MS_dum_all		0.527	88.57
	Intercept	9380.47	R-square	0.59

[1)]Squared semi partial regression coefficients of carcass traits on cow auction price was developed by using Model 4.
R-square, Coefficient of determination for the multiple regression model; MS_dum_all, Subtotal of MS_dum_i (i=2, 3, 4, 5, 6, 7, 8, 9).
**$p<0.01$.

Table 7. Squared semi partial regression coefficients of carcass traits on steer auction price[1)]

	Carcass traits	Parameter (won)	Squared semi-partial correlation	Contribution (%)
Auction Price (only steer)	Back fat thickness	-92.12**	0.035	8.84
	Eye muscle area	20.22**	0.005	1.34
	Carcass weight	1.30**	0.000	0.10
	Raising period	-1.72**	0.004	0.92
	Holyday effect	645.15**	0.013	3.36
	MS_dum2	1,719.36**	0.006	1.39
	MS_dum3	1,850.90**	0.007	1.66
	MS_dum4	3,713.50**	0.027	6.89
	MS_dum5	3,749.51**	0.028	6.98
	MS_dum6	4,995.58**	0.049	12.40
	MS_dum7	5,189.18**	0.052	13.01
	MS_dum8	6,551.40**	0.079	19.76
	MS_dum9	7,338.80**	0.093	23.35
	MS_dum_all		0.527	88.57
	Intercept	10,784	R-square	0.58

[1)]Squared semi partial regression coefficients of carcass traits on steer auction price was developed by using Model 4.
R-square, Coefficient of determination for the multiple regression model; MS_dum_all, Subtotal of MS_dum_i (i=2, 3, 4, 5, 6, 7, 8, 9).
**$p<0.01$.

factors to the Hanwoo beef unit price among all the models. Further studies would be needed to obtain more accurate results, and these study will contribute to establishing breeding.

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