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DEVELOPMENT OF AN ECONOMETRIC MODEL CASE STUDY: ROMANIAN CLASSIFICATION SYSTEM

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Abstract:

The purpose of the paper is to illustrate an econometric model used to predict the lean meat content in pig carcasses, based on the muscle thickness and back fat thickness measured by the means of an optical probe (OptiGrade PRO).The analysis goes through all steps involved in the development of the model: statement of theory, specification of the mathematical model, sampling and collection of data, estimation of the parameters of the chosen econometric model, tests of the hypothesis derived from the model and prediction equations. The data have been in a controlled experiment conducted by the Romanian Carcass Classification Commission in 2007. The purpose of the experiment was to develop the prediction formulae to be used in the implementation of SEUROP classification system, imposed by European Union legislation. The research methodology used by the author in this study consisted in reviewing the existing literature and normative acts, analyzing the primary data provided by and organization conducting the experiment and interviewing the representatives of the working team that participated in the trial.

Key words: *econometrics, predictive model, regression analysis, SEUROP system*

1. Introduction

Very simply stated, econometrics means economic measurement. Broadly speaking, econometrics is the field of economics that concerns itself with the application of mathematical statistics and the tools of statistical inference to the empirical measurements of relationships postulated by the economic theory (Green, 2003). It is the social science in which the tools of economic theory, mathematics and statistical inference are applied to the analysis of economic phenomena (Goldberger, 1964). Econometric analysis and the process of developing an econometric model involves the following aspects (Gujarati, 1992): statement of theory or hypothesis; specification of the mathematical model; specification of the statistical or econometric model; collection of data; estimation of the parameters of the chosen econometric model; tests of the hypothesis derived from the model; prediction.

The linear regression model is the most useful tool in the econometrics. It is used to study the relationship of a dependent variable and one or more independent variables. Typically, regression analysis is done for one of two purposes: to predict the value of the dependent variable for individuals for whom information concerning the explanatory variables is available, or to estimate the effect of the explanatory variable on the dependent variable. The generic form of the linear regression model is (Green, 2003):

$$Y = f(X_1, X_2, ..., X_k) + e = b_0 + b_1 * X_1 + b_2 * X_2 + ... + b_k * X_k + e$$

where *Y* is the dependent (explained) variable, X_i are the independent (explanatory) variables, bi are the estimators and *e* is the random disturbance.

2. Research objectives and methodology

The purpose of this paper is to illustrate the construction process of an econometric model used to predict the lean meat content in pig carcasses, based on their muscle and back fat thickness measured by the means of an optical probe (OptiGrade PRO). The data have been generated as the result of a controlled experiment conducted by Romanian Carcass Classification Commission in 2007. The purpose of the experiment was to develop the prediction formulae to be used in the implementation of SEUROP classification system, imposed by European Union (EU) legislation. The research methodology used by the author in this study consisted in reviewing the existing literature and normative acts, analyzing the primary data provided by and organization conducting the experiment and interviewing the representatives of the working team that participated in the trial.

3. Background of the problem investigated

Setting the price for commodity products has always been a critical concept for agricultural producers. Quality standards are based on measurable attributes that describe the value and utility of the product. For example, pig carcass quality standards in European Union are based on the content of lean-meat. According to their leanness (percentage of lean meat in the carcass) the carcasses are divided into six quality grades: S, E, U, R, O and P (Table 1).

Table 1. The EU scale for classification of pig carcasses

Quality grades	Lean meat as percentage of carcass weight
S	> 60%
E	55% – 60%
U	50% - 55%
R	45% - 50%
O	40% - 45%
P	< 40%

Source: European Parliament and The Council of EU, Regulation (EU) No 1308/2013

The purpose of the quality grades is to set a common language among buyers and sellers, serving as a basis for domestic and international trade. At the same time, the buyers purchasing officially graded pig carcasses can be assured the product meets the standards indicated on the label.

The leanness of pig carcasses directly affects their market price. Therefore, the estimation of the lean meat content in pig carcasses, followed by a fair payment system based on carcass weight and its composition are the main objectives of the classification system. Starting the 1st of January 1985, the pig carcass classification activity became mandatory in EU member states (Council Regulation (EEC) No. 3220/1984). That means, the abattoirs have to weigh the carcasses immediately after the slaughter, to assess the lean meat content in each carcass, to divide the carcasses into S, E, U, R, O, P classes and to mark them accordingly.

Romania applied the EU legislation in the sector of pig classification starting March 2006. Since then, the abattoirs predict the lean meat content of the pig carcass on the basis of fat thickness and muscle thickness measurements taken with two optical devices: OptiGrade PRO (OGP and Feat’o’Meater (FOM) or with the ruler.

4. Mathematical model

In Romania, pig classification activity is based on objective estimation of the leanness (lean meat content) of the carcass, using methods, devices and software that must be previously approved by the European Commission (EC). In the slaughterhouses, at the end of slaughter lines a set of measurements (back fat thickness - FT and muscle thickness - MT) are taken at a well defined site of the carcass, by means of two optical devices or by the rulers. These measurements are then used in prediction equations to determine the percentage of the lean meat (LMP) in the carcass. The mathematical model is:

$$LMP = b_0 + b_1 * FT + b_2 * MT$$

Where:

LMP = predicted lean meat percentage (%)

FT = back fat thickness (mm)

MT = muscle thickness (mm)

b_0, b_1, b_2 = regression coefficients (estimators)

5. Description of the experiment

During the period May-June 2007, Romanian authorities (Carcass Classification Commission) conducted an experiment in two Romanian slaughterhouses. The purpose of this experiment was to determine the prediction formula for the estimation of the lean meat percentage of pig carcasses, using OGP optical probe, and to obtain the authorization to use this device from the EU

Management Committee for Pig Meat. The whole process of determination of leanness (sampling, statistical analysis and statistical criteria of accuracy), had to comply with the EU regulation regarding the methodology of estimation the muscle tissue percentage in pig carcasses (Commission Regulation (EC) No. 1197/2006).

5.1. Sampling

The European Regulation stipulates that the prediction formulae to estimate the lean meat percentage in pig carcasses is determined in the standardized method of dissection, based on a "representative sample of the national or regional pig-meat production concerned, consisting of at least 120 carcasses" (Commission Regulation (EC) No. 1197/2006).

The representatives of the Carcass Classification Commission conducted the dissection trial in May-June 2007. The Danish Meat Research Institute supervised the carcass selection, the muscle and back-fat measurements and the dissection processes. A stratified random sampling method was applied to select 145 carcasses (72 were females and 73 castrated males), weighing within the limits of technical norms (50-120 kg). The selected carcasses followed the fat thickness national distribution. In order to cover the national breed variation, the animals were selected from 14 farms, mainly large producers, situated throughout the country.

5.2. Collection of data

Among the data collected from the 145 carcasses during the experiment and recorded by the representatives of the Romanian Carcass Classification Commission were: hot carcass weight, back-fat thickness, muscle thickness and lean meat percentage. The summary of the data is presented in Table 2.

Table 2: Description of selected carcasses

Measure (n=145)	Mean	Min	Max	Std.dev.
Hot carcass weight, kg	79.9	58.6	100.7	7.77
Back fat thickness, OGP, mm	16.54	9.40	30.80	4.95
Muscle thickness, OGP, mm	52.0	32.1	82.2	9.88
Lean meat percentage, %	56.30	38.61	66.89	5.30

Source: Carcass Classification Commission

5.2.1. Independent variables: muscle thickness (MT) and back fat thickness (FT)

After the 145 selected animals were weighted, they were split into halves and hung on a separate line. The process was done within 45 minutes from the moment the pigs were slaughtered. The carcasses were presented according to EU standard requirements. Then, the measurements of the back fat thickness and muscle thickness with the OGP optical device were carried out by four experienced, according to a preestablished plan. The measurements were done with OGP equipment, on the left half carcass, at 7 cm from the split line, between the 3rd and the 4th last rib.

5.2.2. Dependent variable: percentage of lean-meat in the carcass (LMP)

Within 24-48 hours postmortem, in a separate room with the temperature of under 10º C, the dissection took place. Each carcass had been assessed by one experienced butcher. The dissection of the four main parts of the carcass (ham, shoulder, loin and ribs) had been performed by and ten butchers. The dissection process was done manually. The lean meat percentage was determined by the reference to the dissection method stipulated in Commission Regulation (EC) No. 1197/2006.

6. Estimation of parameters in the econometric model

In order to determine the prediction formulae, the linear regression method based on the least square technique has been applied. The prediction formula reflects the relationship between the dependent variable (lean meat percentage, LMP) and the two estimators (back fat thickness, FT, and muscle thickness, MT). The Excel output of the regression analysis reflected the following results (Figure 1):

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.891207957
R Square	0.794251623
Adjusted R Square	0.791353758
Standard Error	2.422382919
Observations	145

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	3216.589408	1608.294704	274.081701	**1.76557E-49**
Residual	142	833.2473388	5.867939006		
Total	144	4049.836747			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept (b_0)	61.21920467	1.696676522	**36.08183638**	2.15052E-73	57.86519592	64.57321342	57.86519592	64.57321342
X Variable 1 (b_1)	-0.77664787	0.045876644	**-16.92904706**	7.05079E-36	-0.867337324	-0.685958417	-0.867337324	-0.685958417
X Variable 2 (b_2)	0.152391348	0.02298815	**6.629126355**	6.53326E-10	0.106948122	0.197834574	0.106948122	0.197834574

Figure 1 Regression analysis – summary output

As can be seen from the regression analysis output, the econometric model developed is valid, since partial t values indicate that both independent observations FT and MT are statistically significant predictors of LMP (the tabled t value for 142 degrees of freedom at 0.05 level of confidence is 1.98, lower than the computed t value). The correlation coefficient is very close to 1 (multiple R = 0.89). It reflects a high association between the LMP and the FT and MT (more than 79% of the variation of LMP is explained by the two estimators, FT and MT, as reflected by the coefficient of determination R square). The model is statistically significant since F-test is significant (F = 274.08), $p<0.05$). The root mean squared error of prediction (RMSEP) was computed on all 145 data by means of SPSS software. Its value, RMSEP = 2.45933, is

less than 2.5 and so, it meets the EU requirements (Commission Regulation (EC) No. 1197/2006, article 1, paragraph 1).
In conclusion, the prediction formula to be used in case of the OGP equipment was:

$$LMP = 61.21920 - 0.77665 * FT + 0.15239 * MT$$

Where:
LMP = predicted lean meat percentage (%)
FT = back fat thickness (mm)
MT = muscle thickness (mm)

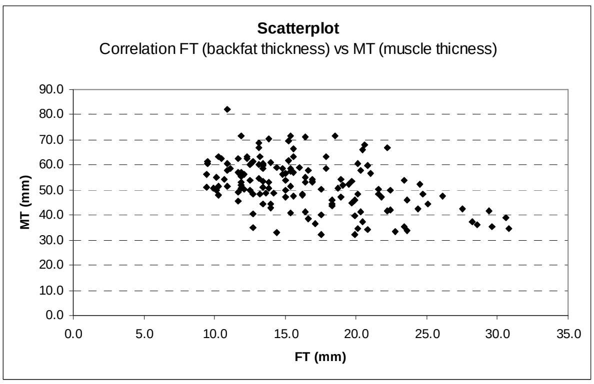
7. Testing the assumptions of the classical linear regression model

The classical linear regression model consists of a set of assumptions about how a data set is produced by an underlying data generating process (Green, 2003). The economic insights yielded by a regression model may be inefficient in case any of these assumptions is violated.

7.1. Lack of multicollinearity in the predictors

Sometimes, the independent variables may measure the same phenomena. As a consequence, the correlation among them is strong and problems of understanding which independent variable contributes to the variance explained in the dependent variable might appear (multicollinearity). In order to detect multicollinearity in the SEUROP regression model, the scatter plot of the two predictors (FT and MT) has been done (Figure 1).

Figure 1 Scatter plot for detecting multicollinearity in the predictions



The two variables seem to be slightly correlated: FT goes down when MT goes up. Since the correlation is on a moderate level (Pearson correlation factor is 0.46) it can be concluded that from the point of view of the multicollinearity assumption, the regression model does not need any transformation.

7.2. Linearity of the relationship between dependent and independent variables

A valid econometric model assumes that: (a) the relationship between dependent (LMP) and each independent variables (FT and MT) needs to be linear and (b) the relationship between the dependent variable (LMP) and the independent variables collectively (FT and MT) needs to be linear as well. This assumption might be checked by scatter-plots (Figure 2) and partial regression plots (Figure 3).

Figure 2 Scatter plots for detecting linearity of the relationship between dependent (LMP) and independent variables (FT and MT)

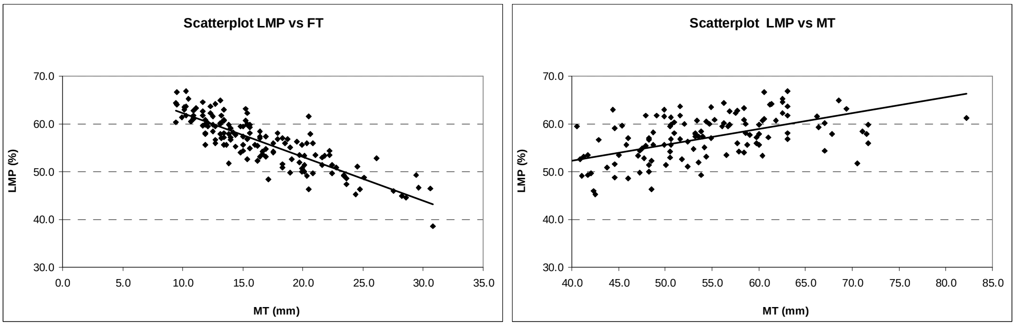
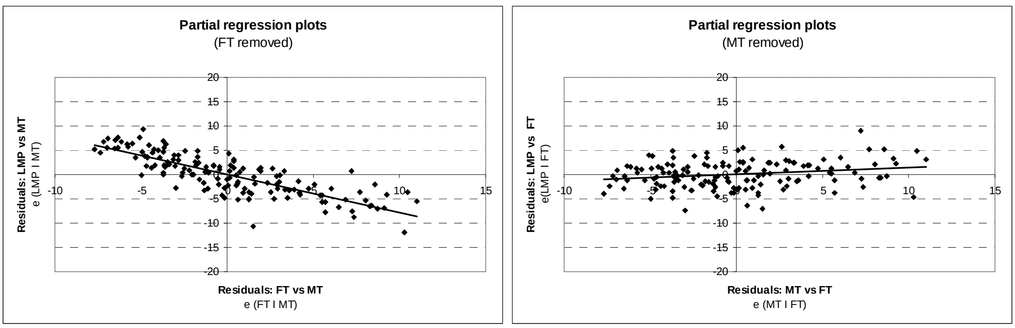


Figure 3 Partial regression plots for detecting linearity of the relationship between dependent (LMP) and independent variables (FT and MT)

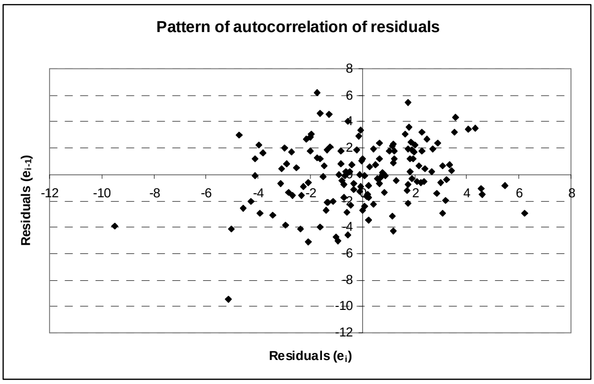


The scatter plots and partial regression plots reflect that the linear relationship between dependent and independent variables, with no need of any transformation in the existing regression model.

7.3. Lack of autocorrelation of residuals

Residual autocorrelations (lack of independency) implies that the ordinary least square estimators, although linear and unbiased, are not efficient; that is, they are not the best linear unbiased estimators. The pattern of autocorrelation of residuals in the under investigation regression equation is presented in Figure 4.

Figure 4 Residuals correlogram

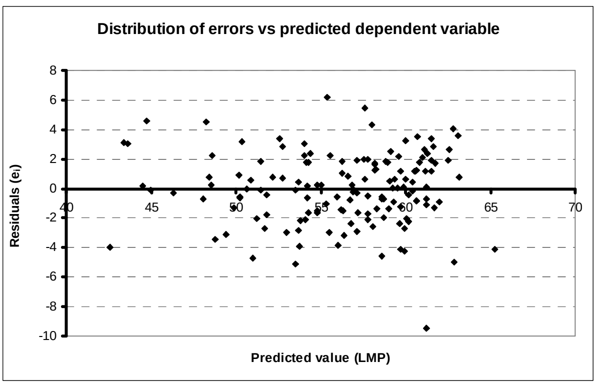


Visual inspection of the residuals correlogram shows that there is little significant correlation in the residuals. Pearson correlation factor is 0.24, suggesting a small correlation between residuals e_i and $e_{i-1.}$ As a consequence, there is very little room for improvement in the regression model, which does not justify the effort.

7.4. Homoscedasticity of errors

Homoscedasticity of errors means that the variance of each residual (e_i) is constant. In this case, for all values of the predicted dependent variable (LMP), the residuals plot has approximately the same width. Figure 5 illustrates is no suspicion of heteroscedasticity in the existing model.

Figure 5 Distribution of errors versus predicted lean meat percentage



7.5. Normality of the error distribution

Normality of the error distribution is checked by visually inspecting the Histogram (Figure 6) and Normal P-P plot (Figure 7) of residuals.

Figure 6 Histogram of residuals

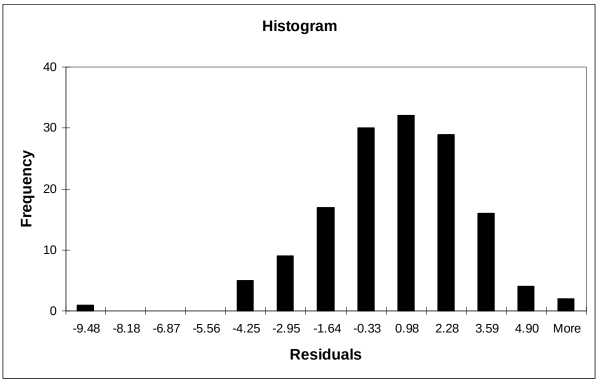


Figure 7 Normal P-P plot of residuals

Figure 6 shows us that the histogram of residuals is approximate symmetric bell-shaped, evenly distributed around zero. The normality plot of the residuals is pretty much linear (Figure 7). This indicates that the normality of errors assumption is likely to be valid.

8. Conclusions

Romanian Classification Commission submitted the results of the experiment to European Commission (EC) by the end of 2007. EC considered that the prediction equation and the assessment methods described above met the statistical requirements imposed by EU legislation and approved the use of the OGP equipment for grading pig carcasses in Romania (Commission Decision 2008/169/EC). EC decision had been transposed into the national legislation under the Order of Romanian Ministry of Agriculture and Rural Development No. 460 from 17 July 2008. Starting 21th of August 2008, the use of the new prediction equation became compulsory.

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