doi: 10.17221/268/2017-AGRICECON

The cybernetic stability of microeconomic variables in the agricultural sector: A case study from the agritourism field

Tomas MACAK*, Jan HRON

Department of Management, Faculty of Economics and Management, Czech University of Life Sciences Prague, Prague, Czech Republic

*Corresponding author: macak@pef.czu.cz

Macak T., Hron J.: **The cybernetic stability of microeconomic variables in the agricultural sector: A case study from the agritourism field**. Agric. Econ. – Czech, 63: 531–538.

Abstract: Complexity in the management and variability of environmental factors in the agricultural, environmental and food industries has brought about the demand for developing robust methods that allow multiple variables to operate with compound dependencies and are inert to changing situation conditions (e.g. changing the agrarian policy of the state). Therefore, new attempts are being made to cope with these problems (i.e. complexity in control and the instability of initial conditions). There is one solution based on interdisciplinary or transdisciplinary approaches; these methods were chosen for our case study on the agribusiness sector, where we use economic variables in the transformed form. This transformation allowed us to determine the optimal parameter settings (regarding factor instability) and the potential for regulating agribusiness activities using the corporate cybernetic diagrams. Estimations of the position and variability of the input values of the factors were carried out using a random vector. The practical experiment was conducted on the Agro-farm Krasna as a case study, thereby making it easy to repeat the designed procedure.

Keywords: agritourism, cybernetic regulation, economic variables, factorial design, transformation

Several researchers and scientists have used different approaches to clarify the context of key factors involved in agribusiness and agritourism. Over the decades, notable efforts have been made for developing reliable prediction and evaluation methods in different scientific fields. One such effort emphasises research on the legal and factual forms of entrepreneurial organisations that best serve to overcome the entry barriers to agricultural business (Beener 1984; Cook 1995; Foreman and Whetten 2002; Ingram et al. 2010; Boone and Ozcan 2014).

Another area of research focusses on alternative methods of statistical testing, which are determined by factors influencing farming outcomes. Such tests often centre on hierarchical linear models (Rune 2005; Armstrong 2012; Brenes 2017), or they are aimed at the elimination of information entropy in the agricultural business (Desarbo et al. 2005; Marx 2010; Fiss 2011; Kweon 2012; Syrovatka et al. 2015; Kolackova et al. 2017).

A social approach, or social responsibility, is also an important area of interest in research agribusiness (Camacho et al. 2016; Spann 2017). In a broader context, research has focussed on rural development planning (Santos-Gomez 2017). Problems in the economic management of agricultural companies were addressed, for example, in Babovic et al. (2013), Straka and Stavkova (2015) and Tomsik (2016). In recent publications, the phenomena of agribusiness predictions and risk management have emerged (Jankelova et al. 2017).

Overall, agribusiness has been discussed in over 1200 articles published on the Web of Knowledge over the last 5 years. Thus, the agribusiness topic an area of high research intensity. Thus, the present article deals with the integration of four approaches

The paper was elaborated in the frame of solving project IGA 20171020 (Czech University of Life Sciences in Prague).

doi: 10.17221/268/2017-AGRICECON

Table 1. Combined function of a random vector of fundamental events in the field of agribusiness

$X_{Si}\backslash X_{St}$	0	1	2
0	0.60 × 0.60 = 0.3600	2 × 0.60 × 0.32 = 0.3840	0.32 × 0.32 = 0.1024
1	2 × 0.08 × 0.60 = 0.0960	2 × 0.08 × 0.32 = 0.0512	0
2	0.08 × 0.08 = 0.0064	0	0

(random vector, cybernetic stability, microeconomic control, statistical optimization) used to determine the economic stability and efficiency of agribusiness.

MATERIAL AND METHODS

Determining the stable profitability area of the selected agribusiness

Determining a stable area means finding parameters by which agribusiness can deliver a profitable result in the allotted timeframe. The probabilities that there will be a high, moderate or negligible change in the conditions (over the planned period of 2 years) are 0.1, 0.3 and 0.6, respectively. These probabilities were determined by the relative frequency in the retrospective period. A sharp change in the situation conditions will cause a 40% or greater sales difference compared to the planned value, a moderate change will cause a 10–40% difference and a negligible change will result in less than a 10% difference.

Based on the retrospective values, we assume that during the projected period (generally, the lifetime of the investment), there will be two key events affecting agribusiness sales; and these events will be mutually independent of the level of sales in the agribusiness. The random vector $\mathbf{X} = (X_{SI}, X_{St})^T$ is the number of fundamental events during the reporting period (lifespan of the investment), which have strong (X_{Si}) and medium (X_{St}) effects on agribusiness sales. To determine the initial conditions for stable management of the agribusiness, it is necessary to delineate the probability that the number of fundamental events with a strong effect on the level of sales of agribusiness will be lower than the number of events with a medium effect on sales in agribusiness. For this purpose, we first determine the range of values of the random vector X. The range of values of the random vector X is given by a combination of three realistic levels of change of situational conditions (destabilisation), assuming two fundamental changes:

$$\{(0, 0)^T; (0, 1)^T; (0, 2)^T; (1, 0)^T; (1, 1)^T; (2, 0)^T\} \quad (1)$$

The random phenomena (calculated by the retrospective values), $(1; 2)^T$; $(2; 1)^T$; $(2; 2)^T$, are not considered possible, since they represent more than two fundamental events. Further, we determine the so-called associated probabilistic function of the random vector X according to the following formula:

$$\sum_{i=1}^{n_1}\sum_{j=1}^{n_2} P\left(X = x_i \wedge Y = y_j\right) = 1,\ n_1 \geq 1,\ n_2 \geq 1$$

where $(X = x_i \wedge Y = y_j) = (X = x_i, Y = y_j) = p(x_i, y_j)$ indicates the associated probability function of a random vector X. After reaching the individual probability of occurrence of events fundamental to the previous formula, we obtain the simple Tables 1 and 2.

Now we can determine the chances that there will not be extreme sales variability over the planned period. In other words, the number of key events with a large effect on the level of sales of agribusiness will be less than the number of events with a medium effect on agribusiness sales. This chance is given by the sum of the associated probability values above the main diagonal of Table 3:

$$P(X_{Si} < X_{St}) = 0.36 + 0.09 + 0 = 0.45 \quad (2)$$

The sum of the combined probability values above the main diagonal is the coefficient that needs to multiply the predicted cash flow from each agribusiness activity to reach the area of stable cash flow.

Table 2. Marginal probability function for the agribusiness random events vector

$X_{Si}\backslash X_{St}$	**0**	**1**	**2**	**P(x_{Si})**
0	0.3600	0.3840	0.1024	**0.8464**
1	0.0960	0.0512	0	**0.1472**
2	0.0065	0	0	**0.0064**
P(x_{St})	*0.4624*	0.4352	0.1024	**1.0000**

Table 3. Probability that the number of events with a large effect on the level of agribusiness sales will be negligible

$X_{Si}\backslash X_{St}$	**0**	**1**	**2**
0	0.36	0.36	0.09
1	0.12	0.06	0
2	0.01	0	0

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This area indicates the achievable cash flow values in the unfavourable development of the substantial business environment.

In a steady state, a businessperson only operates with the factor gain; that is, the sum of profits is equal to zero:

$$\sum_{i=1}^{3} P_i = 0 \quad (3)$$

We write a set of equations for individual loops of cash flow from condition (4):

$$C_1 \times CF_A + C_2 \times (CF_A - CF_B) - R_1 + R_2 = 0 \quad (4)$$

$$C_2 \times (CF_B - CF_A) + C_3 \times CF_B - R_3 - R_2 = 0 \quad (5)$$

For example, we can modify the system using its determinants:

$$(C_1 + C_2) \times CF_A + C_2 \times CF_B = R_1 + R_2 \quad (6)$$

$$-C_2 \times CF_A + (C_2 + C_3) \times CF_B = R_3 + R_2 \quad (7)$$

Before proceeding to attain the values in Table 4 for the system of equations (5) and (6), it is necessary to correct for dimensional variables of annual revenues R_1, R_2 and R_3. In economic terms, total revenue is the sum of total profits and total costs during a given period. Therefore, it has a CZK/year or EUR per year dimension. The cybernetics concept of total revenue has CZK^2/year, or EUR^2/year dimensions. Thus, we transform the one-dimensional expressed revenues into two-dimensional expressions to match the dimensional expression of the other members of equations (7) and (8). Thus,

$$R_i = C_i + CF_i \xrightarrow{transformation} R_i^* = C_i \times CF_i = R_i \times C \times C_i^2 \quad (8)$$

We came can modify this equation algebraically as follows:

$$R_i^* = (C_i + CF_i) \times \frac{C_i \times CF_i}{C_i + CF_i} = R_i \times \frac{C_i \times CF_i}{C_i + CF_i} = R_i \times \frac{C_i \times (R_i - C_i)}{C_i + (R_i - C_i)} = R_i \times \frac{R_i \times C_i - C_i^2}{R_i} = R_i \times C_i - C_i^2 \quad (9)$$

Substituting the values from Table 4 in formula (9), we obtain the dimensionally corrected revenues:

$$R_1^* = R_1 \times C_1 - C_1^2 = (16 \times 20 - 20^2) \times 10^6 = -80 \times 10^6 \text{ CZK}^2\text{/year} \quad (10)$$

$$R_2^* = R_2 \times C_2 - C_2^2 = (4 \times 10 - 10^2) \times 10^6 = -60 \times 10^6 \text{ CZK}^2\text{/year} \quad (11)$$

$$R_3^* = R_3 \times C_3 - C_3^2 = (10 \times 8 - 8^2) \times 10^6 = 16 \times 10^6 \text{ CZK}^2\text{/year} \quad (12)$$

After substituting the dimensionally corrected revenues, we obtain

$$(C_1 + C_2) \times CF_A + C_2 \times (CF_A - CF_B) = R_1^* - R_2^* \quad (13)$$

$$- C_2 \times CF_A + (C_2 + C_3) \times CF_B) = R_3^* + R_2^* \quad (14)$$

Substituting the values from Table 4 into equations (13) and (14), we obtain the following system:

$$30CF_A - 10CF_B = -20 \quad (15)$$

$$-10CF_A + 18CF_B = -44 \quad (16)$$

Then, we identify the determinants of the system, as well as the determinants of (a) cash flow and (b) cash flow loops:

$$D_s = \begin{Vmatrix} 30 & -10 \\ -10 & 18 \end{Vmatrix} = 440 \quad (17)$$

$$D_A = \begin{Vmatrix} -20 & -10 \\ -44 & 18 \end{Vmatrix} = -800 \quad (18)$$

$$D_B = \begin{Vmatrix} 30 & -20 \\ -10 & -44 \end{Vmatrix} = -1520 \quad (19)$$

Table 4. Designation of quantities from scheme 1

Designation	Variable	Dimension of variable
R_1	Annual revenue (revenue) of accommodation (16)	
R_2	Annual revenue from meals (4)	
R_3	Annual yield from agribusiness attractions (10)	
C_1	Annual cost of accommodation (20)	
C_2	Annual cost of meals (10)	
C_3	Annual cost of operating attractions (8)	$10^6 \times$ CZK/year
CF_1	Annual cash flow from accommodation	
CF_2	Annual cash flow from meals	
CF_3	Annual cash flow from operations attractions	
CF_A	Annual cash flow, loop A	
CF_B	Annual cash flow, loop B	

doi: 10.17221/268/2017-AGRICECON

The cash flow of loop A, which expresses the revenue and cost from annual accommodation and catering, is equal to the quotient of the determinant *DA* and system determinant D_S:

$$CF_A = \frac{D_A}{D_S} = \frac{-800}{440} = -1.818 \times 10^6 \text{ CZK/year} \quad (20)$$

Similarly, the size of the cash flow of loop B, which expresses revenue and cost from the annual agritourism attractions in interaction with loop A (accommodation and meals), is equal to the quotient of the determinant D_B and system determinant *Ds*:

$$CF_B = \frac{D_B}{D_S} = \frac{-1520}{440} = -3.455 \times 10^6 \text{ CZK/year} \quad (21)$$

The cash flow (simplified as profit + depreciation) from the operation of the accommodation facility, as shown in Figure 1, is equal to CF_A:

$$CF_1 = CF_A = -1.818 \times 10^6 \text{ CZK/year} \quad (22)$$

The cash flows from agritourism and catering services are equal to CF_B, as shown in Figure 1:

$$CF_2 = CF_B = -3.455 \times 10^6 \text{ CZK/year} \quad (23)$$

Cash flow from agritourism attractions is determined by the difference in cash flows from accommodation and catering services:

$$CF_3 = CF_1 - CF_2 = -1.818 - (-3.455) = 1.637 \times 10^6 \text{ CZK/year} \quad (24)$$

CF_1 and CF_2 have an orientation against the revenue R_1 and R_3 flows in Figure 1, which contradicts the microeconomic theory of cost-revenue analysis. For this reason, these flows are negative. These negative flows indicate the loss of accommodation and catering businesses. The results of losses and profits differ from those of the simple revenue and cost comparisons, as the cybernetic equilibrium values are determined. These are values that are achievable with the current resource configuration. From a profitability standpoint, it seems that only the business of the agrarian attractions is profitable, so it is appropriate to operate them. Following the introduction of the correct cash flow orientation in Figure 1, we see that cash flow (CF_3) produces a positive (synergistic) interaction effect only with CF_2, and it exhibits a negative (antagonistic) interaction effect with CF_1. Further, there is an antagonistic effect between CF_1 and CF_2. Thus, customers are considered complementary to attractions and dining. Due to these negative interactions, financial losses are likely to occur in well-priced services.

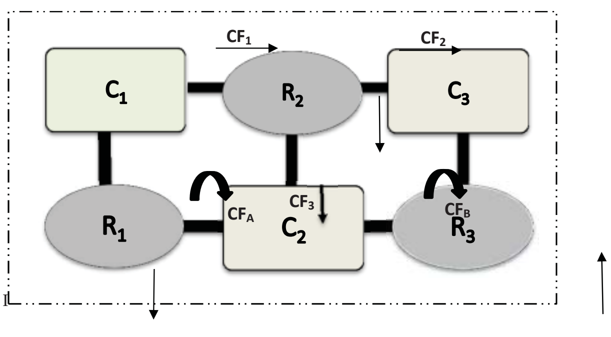

Figure 1. Scheme of cash flow during interaction in two loops of agribusiness

We use the sum of the combined probability values above the main diagonal in Table 3 to determine a stable area of individual cash flows. This sum represents the coefficient by which we need to multiply the equilibrium cash flow to determine the stable area. A stable area shows where there is a defined boundary of economic performance while configuring services. Or vice versa, it shows achievable positive results in unfavourable development of the organisation's essential environment. Thus,

$$CF_{1S} = P(X_{Si} < X_{St}) \times CF_1 = 0.45 \times (-1.818) = -0.8181 \times 10^6 \text{ CZK/year} \quad (25)$$

$$CF_{2S} = P(X_{Si} < X_{St}) \times CF_2 = 0.45 \times (-3.455) = -1.554 \times 10^6 \text{ CZK/year} \quad (26)$$

$$CF_{3S} = P(X_{Si} < X_{St}) \times CF_2 = 0.45 \times 1.637 = 0.737 \times 10^6 \text{ CZK/year} \quad (27)$$

Optimisation design for setting up various agribusiness activities

After finding the mean values of cash flow from individual agribusiness activities and their stochastically stable areas, we can optimise individual activities (services) that generate cash flow. For economic reasons, we will limit ourselves to the optimisation of CF_1, that is, the optimisation of sustainable profitability from operating agritourism accommodation. We use a full-factorial design when we consider two aggregated factors, namely cost (factor A) and quality of service (factor B).

According to Anthony (2003), the full factorial experiment is a plan consisting of two (or more) factors, and each factor has discrete possible levels. The experimental response trials take on all possible

doi: 10.17221/268/2017-AGRICECON

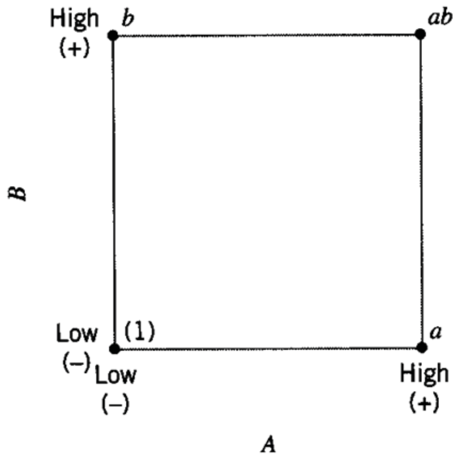

Figure 2. Design representing a square experimental space

trials of these levels across all such factors. In our case, only two factors (A and B) are considered, and each factor includes just two levels. Then, the factorial experiment has four treatment combinations, and this is usually called a 2 × 2 factorial design. This type of factorial experiment uses explicit marking for individual levels (adjustments), as shown in Figure 2.

Our design focusses on the main effects of factor A and factor B, as well as the main effect and interaction between factors A and B. The effects are calculated as the average response for the top level minus the average response factor for the lower level factor. A large effect indicates a significant factor (or interaction). Contrasts can be computed and used to estimate the effects, and then the sum of the squared deviations can be calculated.

Let the terms (1), a, b and ab represent all the four combinations of the levels of the two factors, while n is the number of replications of this proposal. Then, an estimation of effect A is as follows:

$$A = \bar{y}_{A^+} - \bar{y}_{A^-} = \frac{a+ab}{2n} - \frac{b+(1)}{2n} = \frac{1}{2n}\left[a+ab-b-(1)\right] \quad (28)$$

Moreover, the estimation of effect B is

$$B = \bar{y}_{B^+} - \bar{y}_{B^-} = \frac{b+ab}{2n} - \frac{a+(1)}{2n} = \frac{1}{2n}\left[b+ab-a-(1)\right] \quad (29)$$

Finally, the estimation of the effect of AB interaction is

$$AB = \frac{ab+(1)}{2n} - \frac{a+b}{2n} = \frac{1}{2n}\left[ab+(1)-a-b\right] \quad (30)$$

The derivation of formula (28) (29) (30) is published for example in Montgomery (2012). A large effect indicates a significant factor (or interaction). Contrasts can be computed and used to estimate the effects and then calculate the sum of squared deviations.

Our results of the analysis are shown in Table 6. For significance test, we have selected significance levels of a = (0.05). If the so-called p-value is less than the significance level (0.05), the factor or interaction effect is then considered to be statistically significant. For this optimization process, main effects quality and, the interaction between price and quality are statistically significant. These effects have a significant impact on the average revenue from the agritourism. The calculated effect factor in the coded values (response factor to change from –1 to +1) is in the first column of Table 3. The second column is represented by the regression coefficient (that is a half effect of each factor). The statistical significance of each factor or interaction, expressed as a p-value, is noted in the fifth column.

The next step is based on the estimation of the regression model that uses information from the

Table 5. List of process parameters for the experiment

Trial (Run)		Factor A	Factor B	Cash flow for different accommodation services (10^4 × CZK/month)				Total cash flow
1	(1)	–	–	–1.51	–1.69	–1.34	–1.44	–5.98
2	a	+	–	–3.47	–2.86	–3.21	–3.09	–12.63
3	b	–	+	1.32	1.27	1.15	0.94	4.68
4	ab	+	+	2.73	3.05	3.12	2.98	11.88

Table 6. Estimated effects and coefficients for agritourism revenue

Term	Effect	Coef	SE coef	T-value	P-value	VIF
Constant		–0.1281	0.0474	–2.70	0.019	
A – PRICE	0.0687	0.0344	0.0474	0.73	0.482	1.00
B – QUALITY	4.3962	2.1981	0.0474	46.38	0.000	1.00
A – PRICE × B – QUALITY	1.7312	0.8656	0.0474	18.27	0.000	1.00

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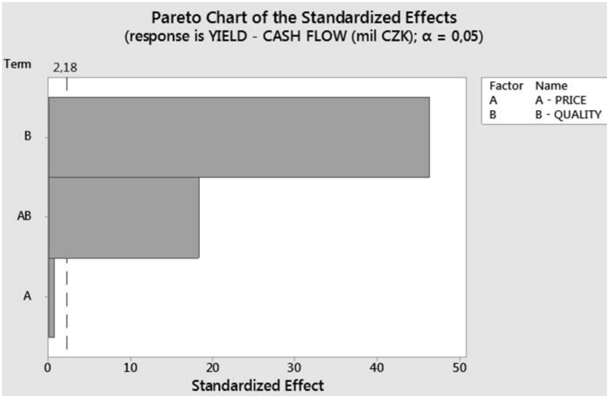

Figure 3. Pareto plot shows one significant parameter and one significant interaction

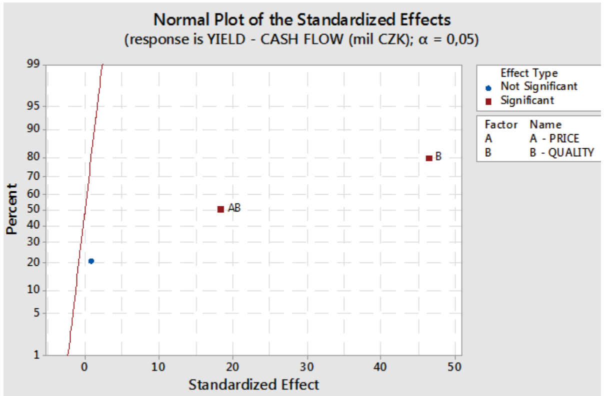

Figure 4. Normal plot of the standardized effect shows the same results as Pareto plot (factor B – service price is not significant)

factorial design. The regression model is estimated by the following form (Montgomery 2012):

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{12} x_1 x_2 + \varepsilon \quad (31)$$

where β_0 is the overall mean of all observations, and each regression coefficient β_j is equal 1/2 of the effect estimation. Factors A, B are represented by x_1, x_2 and AB interaction by x_1x_2. The lower and upper levels of both factors are assigned by the values $x_j = -1$ and $x_j = +1$.

The regression equation in uncoded units is as follows:

YIELD (CASH FLOW (mil CZK)) = –0.1281 + 0.0344 A (PRICE) + 2.1981 B (QUALITY) + 0.8656 A (PRICE) × B (QUALITY) (32)

where Factor A: an economic factor (here, price of accommodation, low [–] vs. high [+]); Factor B: a technical criterion (technical equipment and quality of accommodation services using a universal production device [–] vs. the use of dedicated production facilities [+]).

DISCUSSION

From the above equation (32) is evident, that the quality of agro-tourism services is the most important factor and have a positive effect on revenues. Surprisingly, the price is not a significant factor in the revenue itself and also has a positive impact on revenue. Furthermore, the price is the noise response factor. Therefore, there is a requirement to remove the price variable from the equation (32). Besides, the price level of the accommodation is slightly below the accepted value of the customers. The price has a significant impact on sales only in connection with the quality of accommodation. Therefore the price is not considered separately and creates a strong

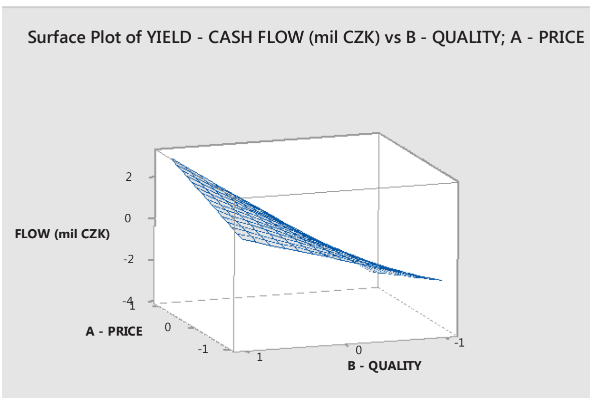

Figure 5. Revenue surface area and its curvature due to the AB interaction

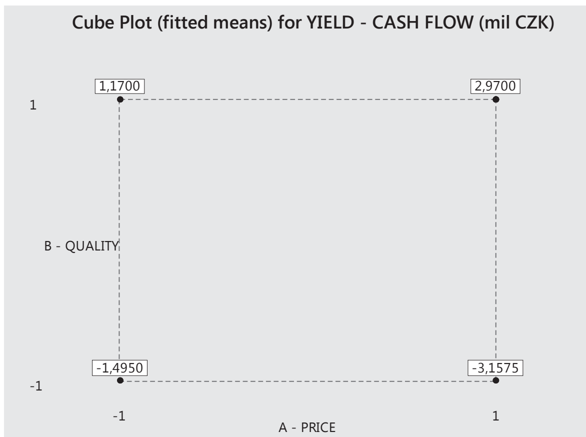

Figure 6. The optimal settings for agritourism accommodation lies in the north-east corner of the experimental square

doi: 10.17221/268/2017-AGRICECON

interaction with the second variable. We need to focus more on service quality and quality-price interaction than on price level during our optimizing process. The same result is also envisioned by the Pareto graph in Figure 3 and by the Normal line in Figure 4. This interaction causes a curvature of the response surface shown in Figure 5. According to Figure 6 and also according to the equation (32), the optimal setting of agritourism accommodation belongs to maximal quality and surprisingly to the maximal value of service prices (upper right corner of the experimental square in Figure 6).

CONCLUSION

The article described the integration of four approaches for determining the economic stability and efficiency of agribusiness. First, a revenue variable was determined using a random vector. Then, the microeconomic quantities of agribusiness (agribusiness) were regulated by a cybernetic two-loop scheme. This expressed the interactional and antagonistic interactions between partial business activities. Furthermore, the cybernetic characteristics of flow variables (costs, revenues, profits) were transformed into dimensional consistency with microeconomic theory. For this purpose, the authors proposed an original method of transforming quantities. Finally, optimisation of the average revenues was carried out using a factorial design. The whole procedure was carried out on Agro-Farm Krasna as a case study, thereby making it easy to repeat the designed procedure.

In subsequent research, the authors want to focus on finding a method for verifying the causality of regression models in agribusiness, presented here as a factorial design. This research promises to increase the reliability of factorial optimisations for the agricultural area (specifically, excluding the influence of the third factor). Moreover, it will bring about a general improvement in the understanding of causal relationships in reducing variability and increasing efficiency in agricultural business.

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Received February 17, 2017
Accepted March 19, 2017