ANALYSIS OF THE RELATIONSHIP BETWEEN THE PERFORMANCE AND THE COMPOSITION OF STUDENT GROUPS IN A PRODUCTION SIMULATION GAME

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ABSTRACT
Simulation games used in educational programs provide an interesting research environment to analyse the successful application of academic knowledge and the effectiveness of teaching. We used a production simulation game in a university master program to measure the production management knowledge of students. This simulation game required marketing, financial and accounting skills as well. During the game, student groups have to decide on the quantity of input in order to achieve better output in a car engine production process.
We applied Data Envelopment Analysis for evaluating and for comparing the performance of student groups. An input oriented CRS model with weight restriction was used to analyse the efficiency of input utilization. Since one of the main results of the game is the generated profit, the handling of negative output data must have been solved.
An interesting research question is how the composition of student groups influences the results. Do student groups with better grades in production management perform better in the game? We used statistical independence tests to analyse the effect of student group composition on performance. We concluded that although there is no relationship between the performance of groups and the average grade of the group members. However, the performance of groups is influenced by the group member with the best grade. This result can be explained by the fact, that generally the best student in a group delivers the necessary knowledge for decision making. Consequently, group formation and task distribution within the groups are important factors which may influence the results

KEYWORDS: performance evaluation, data envelopment analysis, independence test, higher education

INTRODUCTION

Simulation games frequently used in educational programs to support the learning process. First, simulation games help to apply academic knowledge in simplified environment of reality. Simulation games with the generated virtual reality environment can support traditional lecture-based education. Thus, studying can be more successful and effective. Second, simulation games provide a research environment for the evaluation of the performance of student groups and for the analysis of the effectiveness of teaching. In this paper we explore this second issue [5],[8].
Simulation games are applied in several study areas, for example in engineering, in finance, in marketing, in logistics, in commerce, and so on [4],[7]. Generally in simulation games used in management and in economics performance of students is evaluated by financial results. Pure financial analysis may, however, do not explore all aspects of the results. In several cases financial results cannot point out the roots of management problems. Our objective is not to doubt the importance of financial indicators but to extend the boundary of evaluation.
In one of our earlier research we used Data Envelopment Analysis for evaluating the performance of student groups in a production simulation game. The results provided information about the efficiency of input utilization and about the reference sets of inefficient decision making units. Furthermore, the results help management to determine the direction

of change in order to improve efficiency. The results also show how efficient student groups applied their knowledge mastered in different areas of management [6].

In this paper we completed our earlier research with the examination of student group composition. We tried to determine how much the grades of students achieved in the most important areas of management influence the performance of student groups in the simulation game. This is a relevant question both for teachers and for students. We used a statistical test to analyse the relationship between the academic record of the group members and the performance of the groups.

In the following part of this paper first the application environment and the extended version of the basic model with some important results is presented. Next the statistical independence test is introduced. Finally conclusions are drawn and the areas of future research are summarised.

APPLICATION ENVIRONMENT

We applied a production simulation game in the Decision Making in Production and Service Systems course of the Management and Leadership Master Program at the Budapest University of Technology and Economics. During this program students may master the different areas of management. Although we used this simulation game to measure the production management knowledge of students, it required marketing, financial and accounting skills as well. Thus, we evaluate the application efficiency of production, financial and marketing knowledge mastered in the master program.

The objective of the game is to simulate production management decision making in a car engine manufacturing factory. The factory produces three different car engines for five different markets in 7 periods. Each market has its own demand characteristics. The car engines are assembled from parts on assembly lines operated by workers [6].

The purpose of all student groups is to lead their companies effectively and to achieve their operative and strategic goals. For the next production period (year) each student group must make sales and marketing, production, investment and financial decisions. Sales and marketing decisions must be made on purchase price and paying conditions to customers. Production decisions include production planning and manufacturing resource planning decisions. From the third period it is also possible to launch performance improvement projects. The financial decisions include the financing of projects, the investments in production capacity and the application of different type of credits for financing the operation.

After submitting the decisions, the simulation program generates the results of the actual production period. The results are summarized in a production report and in a financial report. Evaluation of the production and of the financial reports, and decision making for the next production period requires the knowledge of several study areas thought in the master program [6].

The different specialized decisions must be harmonized with each other period by period because decisions made in production management influences decisions made in finance and in marketing. For example, forecasting may effect production quantity, inventory control and capacity planning. The change of purchase price may influence future demand of products and also the expected revenue. Satisfaction of higher demand requires more production resource which may lead to investment and/or financial decisions.

At the end of the seventh period of the simulation game we used data envelopment analysis for evaluating the performance of student groups. The applied mathematical models with the results of the simulation game are presented in the next section.

EVALUATE THE PERFORMANCE USING DEA

We used Data Envelopment Analysis (DEA) to compare the performance of several production and/or service systems. We call these production and/or service systems as decision making units (DMU) because they provide similar outputs and they can independently decide on the amount of inputs used.

The objective of DEA is to determine the most efficient decision making units relative to each other, and to assign efficiency measures to each unit. By definition, efficiency is measured as a ratio of weighted output and weighted input. The highest value of efficiency is equal to 1 and the lowest value is equal to 0. In the following, first, the basic model extended by weight restriction is presented. Next, the application of DEA for analysing the performance of student groups in the simulation game is described [1];[2].

1.1. BASIC MODEL WITH WEIGHT RESTRICTION

We used an input oriented constant return to scale (CRS) model with weight restriction known as the CCR Assurance Region model. All notation used in the presented models are listed in Table 1.

The purpose of the simplest DEA model is to find those values of the weights of the different outputs and the weights of the different inputs, which maximize the efficiency of a specific DMU indicated by index 0. The constraints are imposed by the definition of efficiency, that is, the weighted output per weighted input ratio must be less than or equal to 1. The mathematical programming model describing these constraints and goals are the following,

$$\begin{aligned} &\text{Max} \quad \frac{uY_0}{vX_0} \\ &\text{DMU}: \frac{uY}{vX} \leq 1 \\ &u, v \geq 0 \end{aligned} \tag{1}$$

Table 1: List of notation

Parameters:		
Y	-	matrix containing the output values of each DMU,
Y_0	-	vector containing the output values of the DMU examined,
X	-	matrix containing the input values of each DMU,
X_0	-	vector containing the input values of the DMU examined,
Q	-	matrix containing the values of output weight restriction,
P	-	matrix containing the values of input weight restriction,
L	-	vector containing the lower bound of output weights,
U	-	vector containing the upper bound of output weights,
l_{ij}	-	lower bound of the i, j output weight pair,
u_{ij}	-	upper bound of the i, j output weight pair,
L_{ij}	-	lower bound of the i, j input weight pair,
U_{ij}	-	upper bound of the i, j input weight pair,
l	-	vector containing the lower bound of input weights,

Source: the authors own table

When model (1) is solved, generally there are several weights with zero value showing that the DMU has a weakness in the corresponding area. Large differences in weights may cause misleading evaluation. The application of the assurance region method helps to overcome these shortcomings of the previous model, by imposing constraints on the relative magnitude of the weights. We can constrain all of the input (output) weight pairs in the following manner,

$$\begin{aligned} & v_1 l_{1,i} \le v_i \le v_1 u_{1,i} \quad (i = 2,\dots,m) \\ & u_1 L_{1,r} \le u_i \le u_1 U_{1,r} \quad (r = 2,\dots,s) \end{aligned} \tag{2}$$

Fixing the inputs at value 1 and rearranging (1) by eliminating the ratio of variables in model (1), we get the primal input oriented CRS model. Adding the weight restriction constraints we generate the CCR Assurance Region model, which is the following,

$$\begin{aligned} & \text{Max} \quad uY_0 \\ & \text{DMU}: \quad uY - vX \le 0 \\ & \text{Input}: \quad vX_0 = 1 \\ & vP \le 0 \\ & uQ \le 0 \\ & u, v \ge 0 \end{aligned} \tag{3}$$

In practice, for mathematical and for management reasons the solution of the dual form of (3) is used in the following form,

$$\begin{aligned} & \text{Min} \quad \theta \\ & \text{Output}: \quad \lambda Y + Q \ge Y_0 \\ & \text{Input}: \quad -\lambda X + \theta X_0 + P \ge 0 \\ & \lambda \ge 0; \\ & \theta \ge 0; \theta \le 0 \end{aligned} \tag{4}$$

The optimal solution of (4) consists of the efficiency score (θ^*) of DMU 0, and of the optimal values of the dual variable vector λ. The optimal tells the decision maker how much all the input of non-efficient DMUs should be reduced to achieve the efficiency of the best DMUs. It also tells the decision maker the optimal composition of inputs of the reference DMUs. We note that generally, the DEA efficiency scores decreases as a consequence of the application of weight restrictions, that is, a DMU previously characterized as efficient may subsequently be inefficient after such constraints have been imposed. [3]

1.2. ANALYSIS OF THE RESULTS

We applied DEA for evaluating the performance of student groups and for measuring the effectiveness of teaching of the different areas of management. Two outputs and four inputs were considered in the analysis. One of the outputs is *cumulated production quantity* which reflects the effect of production management decisions related to machine and worker capacity, to material requirement planning and to inventory management. The other output is the *net cumulated profit,* which integrates the effect of marketing, production and financial decisions. Net profit may assume negative value, which is not acceptable in basic DEA models, therefore we substituted negative values with zero. (Note, that we are currantly developing models which can assume negative values for outputs.) The four inputs − *cumulated number of workers*, *cumulated number of machine hours*, *cumulated sum of* *moneyspent on raw materials* and *cumulated value of credits* − represent the resources used in the production process. [6]

In one of our earlier paper we recommended the application of smaller group size and higher group number as a future improvement possibility. [6] Using small group number can smooth out the differences in performance. In the case presented in this paper we had 21 three-member groups.

The performance of 21 student groups is compared using an input oriented CCR model with weight restriction. A part of the results are summarized in Table 2.

Table 2: DEA results with production quantity and net profit outputs

1	2	3	4	5
Team	**Output Prod. Quant.**	**Output Net Profit**	**Efficiency θ^***	**Reference set**
1	3 009 915	991 417	**1,0000**	-
2	2 591 996	1 126 668	0,89197	14,16
3	**3 070 324**	338 147	0,92109	
...	**...**	**...**	**...**	**...**
13	2 481 698	1 539 416	**1,0000**	-
14	2 820 976	1 616 111	**1,0000**	-
15	2 616 275	25 650	0,77952	14; 16
16	2 401 985	**2 298 394**	**1,0000**	-
...	**...**	**...**	**...**	**...**
19	2 556 462	905 409	0,88714	14;16
20	2 703 861	1 118 068	0,94613	14;16
21	2 600 980	1 272 617	0,90483	14;16

Source: the authors own table

Table 2 shows the case when efficiency is calculated using two outputs and four inputs. Column 2 shows the total quantity of engines produced during seven production periods. We can see that the highest production quantity is found at group 3, although, the efficiency score and also the net profit of this group is not the highest. This group should have produced this output using less input. Perhaps this group has problems in the area of production management and the suboptimal production decisions caused higher operating cost.

Column 3 shows the cumulated net profit during seven production periods. These results help to evaluate the joint application of marketing, production management and finance related knowledge in the decision making process. The highest value of net profit is appeared at group 16. The efficiency of group 15 is, however, among the lowest, although this group manufactured higher amount of product than group 16. The reason for this is that at group 16 the low production quantity was pared with efficient utilization of resources.

The highest possible efficiency is also indicated at group 1, 13, 14 despite of the fact that their outputs were not the highest. If we use only financial results in the evaluation we may conclude, that only group 16 is efficient. This conclusion, however, would be misleading. Column 4 shows that there are three more efficient groups with different production quantities and net profits. Each of this four groups applied different strategies to operate their systems successfully.

INDEPENDENCE TEST

The Chi-Square test for independence is a nonparametric statistical method which is used to evaluate the independence of two variables. In our case the objective is to determine the relation of the performance of student groups in the simulation game and the composition of groups. We compared the efficiency scores and the academic grade average using the grades of Quantitative Methods, Production and Operations Management, Organisation of Production, Accounting and Corporate Finance courses. Using these datas we generated a frequency table as follows,

Table 3: Frequency table – group academic average and group performance

Average/ Performance	**100-90%**	**90-80%**	**-80%**	∑
3 – 5	7	3	1	**11**
- 3	2	4	4	**10**
∑	**9**	**7**	**5**	**21**

Source: the authors own table

The hypothesis test is performed in the following steps:

1. *Definition of null and alternative hypotheses*:

   H_0: The efficiency scores and the average grade of group members are not related.

   H_1: The efficiency scores and the average grade of group members are related.

2. Fixing *the value of alpha*:

Alpha (α) is the significance level which is the maximum probability that you reject the null hypothesis when the null hypothesis is true. We use the generally accepted 0,05 value of alpha.

3. *Calculation of the degrees of freedom(DF):*

$$DF = (r-1)(s-1), \qquad (5)$$

where r is the number of rows and s is the number of column. In our case the freedom is equal to 2.

4. *Formulation of the decision rule:*

Using the determined alpha and the calculated degrees of freedom, we look up the critical value in the Chi-Square table. We find that our critical value is χ^2_{crit}=5,9915. If the test statistics of χ^2_{cal} is greater than 5,9915, then the critical value H_0 must be rejected and H_1 is accepted.

5. *Calculation of test statistic*

First, we need to calculate our expected values using formula (6).

$$F_{ij} = \frac{f_{i\cdot} \cdot f_{\cdot j}}{N}, \qquad (6)$$

where $f_{i\cdot}$ is the frequancy of row i total and $f_{\cdot j}$ is the frequancy of column j total. We find the expected values by multiplying each row total by each column total, and then diving by the total number of subjects. From the calculated results we can generate the contingency table, presented in Table 4.

Table 4: Contingency table – group academic average and group performance

Average/ Performance	**100-90%**	**90-80%**	**-80%**	∑
3 – 5	7 **4,71**	3 **3,66**	1 **2,61**	**11**
- 3	2 **4,28**	4 **3,33**	4 **2,38**	**10**
∑	**9**	**7**	**5**	**21**

Source: the authors own table

Next, we calculate our Chi-Square value by comparing the observed values to the expected values with the folloing formula,

$$\chi^2_{cal} = \sum_{i=1}^{r}\sum_{j=1}^{s}\frac{(f_{ij} - F_{ij})^2}{F_{ij}} \qquad (7)$$

The calculated test statistic is the following,

$$\chi^2_{cal} = \frac{(7-4{,}71)^2}{4{,}71} + ... + \frac{(4-2{,}38)^2}{2{,}38} = 4{,}66 .$$

6. Interpretation of the results:

If the result of χ^2_{cal} is greater than χ^2_{crit} H_0 is rejected. In our case χ^2_{cal} = 4,66 < χ^2_{crit} =5,9915, consequently H_0 is accepted, that is, the efficiency scores and the average grade of group members are independent.

Do the results mean that university education has no influence on the performance of student groups in this decision making process? In our opinion this is not true. The relation of the academic grades and the performance of student groups, however, require the understanding of the operation of groups. The academic grade of students in a groups is significantly different. We can observed this fact in Table 5 which shows the deviation of the group member's grade averages from the grade average of the group.

Table 5: Deviation of the group members averages

Team	**Relative deviation %**
1	20,74
2	10,83
…	…
6	13,43
7	**36,54**
8	18,10
…	…
17	34,71
18	**28,75**
19	21,65
20	9,85
21	24,44

Source: the authors own table

Table 5 shows that in most cases there is large deviation in the knowledge level of group members. Consequently, we can assume differences in task distribution within a group. We think that the best student in a group delivers the necessary knowledge for decision making. This assumption leads us to the following hypothesis,

H_0: The efficiency score and the average academic record of the *best* student in a group are not related.

H_1: The efficiency score and the average academic record of the *best* student in a group are related.

To test these hypthesis we also used 0,05 value for alpha and our degrees of freedom is the same as earlier DF= 2, thus our critical value is also the same χ^2_{crit} = 5,9915. Using the efficiency scores and the average of the best stundents in all group and calculating the results of formula (6) and (7) we can prepare a new contingency table which is presented in Table 6.

Table 6: Contingency table – best academic average and group performance

Average/ Performance	**100-90%**	**90-80%**	**-80%**	∑
3 - 5	10 **8,57**	3 **5,14**	5 **4,28**	**18**
- 3	0 **1,42**	3 **0,86**	0 **0,71**	**3**
∑	**10**	**6**	**5**	**21**

Source: the authors own table

Calculating the Chi-Square value, we can see that χ^2_{cal} is now greater than 5,9915, that is,

$$\chi^2_{cal} = \frac{(10-8{,}57)^2}{8{,}57} + ... + \frac{(0-0{,}71)^2}{0{,}71} = 7{,}3 > \chi^2_{crit} = 5{,}9915.$$

Based on the results we reject H_0 and accept $H_{1.}$ It means that the efficiency scores and the average academic record of the *best* student in a group are related.

Finally we can determine the streght of the relationship using the Cramer coefficient of association, that is,

$$C = \sqrt{\frac{\chi^2}{N\min[(r-1);(s-1)]}} \quad C = \sqrt{\frac{7{,}3}{21\cdot 1}} = \sqrt{0{,}347} = 0{,}589 \qquad (8)$$

The coefficient shows medium strength of relationship between the two variables. In summary we can conclude, that there is no relationship between the efficiency scores of the groups and the average grade of the group members. The efficiency scores of groups, however, are influenced by the group member with *best* grade. In addition the strength of this relationship is medium which indicate a statistically reliable result.

SUMMARY AND CONCLUSION

In this paper we analysed the relationship between the performance of student groups in a simulation game and the composition of the group. We evaluated the performance of student groups and the effectiveness of the applied knowledge using an input oriented CCR model extended with weight restriction. Then we applied a Chi-Square independence test to analyse the relationship between the measured efficiency scores and the academic records of student groups. We concluded that group formation and task distribution within the groups are important factors which may influence the results. We note that in the case of quantitative variables correlation and regression analysis can provide more accurate results. Regression analysis, however, requires a substantial amount of data. We continue to use this simulation game in the future and we expect that we will have soon enough data to support the conclusion of this paper with stronger statistical evidence.

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