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Multiple regression analysis of performance indicators in the ceramic industry

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Abstract

The present study is a large part proposed within the PhD thesis, which has the aim of enhancing the performances of industrial enterprises with mathematical models. The main goal is to increase the competitiveness, flexibility, adaptability and reactivity of enterprises in the ceramic industry. Since the ceramic sector represents an important part in the manufacturing industry, we focused on this sector, with the aim of evaluating the development of enterprises activating in this domain. The importance of this research lies in its uniqueness and effectiveness, as the performance indicators were analyzed with multiple regression analysis, in the case of an enterprise that produces technical ceramic products. This analysis generally belongs to the multivariate methods, and it is also an explanatory method of analysis. Regression analysis describes the relationship between a dependent variable and several independent variables. The dependent variable consisted in the size of the profit, while the independent variables were the following: self-financing capacity, return on equity, degree of technical endowment, personnel cost per employee and investment per person employed. The selected variables were monitored throughout ten years. The results showed that three of the variables analyzed are very significant predictors for the magnitude of profit. We could also find significant correlations between the analyzed indicators.

Keywords: analysis of variance; Student test; coefficient of determinations – R^2; multivariate analysis of dependencies.

1. Introduction

Industry represents one of the main sectors of national economy, having a pivotal role in achieving and maintaining a high rate of sustainable economic growth [Industrial policy, Chapter 15]. Nowadays, even during

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the crisis, companies appeal to the newest and most effective methods in order to enhance their performance levels which are essential to occupy and maintain a solid place on the market, assuring continuous activity, sustainable development and success. Industry is an indispensable ingredient in the development of a country. In the present study we focused on the ceramic sector, which represents an important part of the manufacturing industry. Several studies and PhD thesis can be found on the ceramic industry of Romania, in which our country's ceramic industry is compared to other European countries' ceramic industry. It is known that from the European countries Romania has been one of the slowest in embracing political and economic changes of the market economy Macquaid, 2001. The aim was to evaluate the development of an enterprise activating in this domain in Romania. This study is a novelty, because this we couldn't find any similar studies and results. In the case of all four performance criterion (competitiveness, flexibility, adaptability and reactivity) we selected multiple indicators. Some of these performance indicators were analyzed with multiple regression analysis, at Chemi Ceramic F Ltd., which is a company that produces technical ceramic products. As the theme chosen for the PhD thesis consists in a research regarding the Romanian ceramic sector's performance growth, we have chosen the above mentioned company, which is the only enterprise in Covasna county that accepted to collaborate with us in this matter.

2. Methodology

The research methodology is based on statistical analysis, which in this paper includes the multiple regression analysis. This type of analysis is used for modeling and analyzing several variables. The multiple regression analysis extends regression analysis Titan et al., by describing the relationship between a dependent variable and several independent variables Constantin, 2006. It studies the simultaneous emotions that some independent variables have over one dependent variable Lefter, 2004, and it can be used for predicting and forecasting. The multiple regression model can be much more realistic than the uni-factorial regression model Goschin and Vatui, 2002.

In our study the dependent variable consists in the size of the profit, while the independent variables are the following: self-financing capacity, return on equity, degree of technical endowment, personnel cost per employee and investment per person employed. All of these variables were monitored throughout ten years.

First we presented the necessary data for the analysis, after which we obtained the regression equation. We calculated the coefficient of determination R^2, which had the aim of indicating the percent of how much of the total variance is explained by the independent variables. Than we turned to F test and to Student test, respectively t with n-(k+1) degrees of freedom, in order to see which hypothesis can be accepted.

3. Multiple regression analysis

The main purpose of this analysis is to know to what extent is the profit size influenced by the five independent variables and what are those measures that should be taken based on the results obtained with using SPSS - Statistical Package for Social Sciences [C. Constantin, 2006]. The table below provides us the data needed to perform the multiple regression analysis.

Table 1. The evolution of the performance indicators at Chemi Ceramic F Ltd. between 2002 and 2011

	Size of the profit (RON)	Self-financing capacity (RON)	Degree of technical endowment (RON)	Return on equity (%)	Personnel cost per employee (RON)	Investment per person employed (RON)
2002	704	350	664.13	9.10	2338.00	175
2003	79515	80742	8009.29	441.70	4494.57	250

2004	8314	18376	4459.30	30.54	4876.70	280
2005	14080	25649	5267.43	40.96	5216.57	310
2006	31154	45516	6072.86	55.58	5565.86	330
2007	33995	47181	5304.00	56.98	9376.00	390
2008	88070	99079	5404.78	75.94	9676.44	540
2009	35968	45827	3065.33	54.33	11960.08	600
2010	85738	97546	2497.82	74.57	12117.55	600
2011	84216	96522	3270.50	75.71	12916.58	670

Source: Balance sheet of Chemi Ceramic F Ltd. for the period 2002-2011

Using the SPSS program kit in the case of multiple regression we have come to the following results:

Table 2. Regression coefficients

Model		Unstandardized Coefficients		Standardized Coeff.	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1444.434	3680.374		.392	.715
	Self-financing capacity	.982	.049	1.012	19.904	.000
	Return on equity	39.806	10.049	.143	3.961	.017
	Degree of technical endowment	-2.032	.480	-.122	-4.232	.013
	Investment per person employed	5.991	23.805	.030	.252	.814
	Personnel cost per employee	-.910	.931	-.099	-.977	.384

a. Dependent Variable: Profit size

Based on the nonstandard coefficients we obtain the regression equation:

$$\hat{y} = 1444.434 + 0.982\,x_1 + 39.806\,x_2 - 2.032\,x_3 + 5.991\,x_4 - 0.910\,x_5$$

where x_1 = self-financing capacity, x_2 = return on equity, x_3 = degree of technical endowment, x_4 = investment per person employed x_5 = personnel cost per employee.

Table 3. Estimation of standard deviation - Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.999[a]	.998	.996	2168.975

a. Predictors: (Constant), Personnel cost per employee, Return on equity, Degree of technical endowment, Self-financing capacity, Investment per person employed

The coefficient of determination R^2 indicating the percent of how much of the total variance is explained by the independent variable is 99.80% (Table 3). The analysis of variance for multiple regression will be made starting from the following results:

Table 4. Variation analysis - ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.087E10	5	2.174E9	462.098	.000[a]
	Residual	18817814.997	4	4704453.749		
	Total	1.089E10	9			

a. Predictors: (Constant), Personnel cost per employee, Return on equity, Degree of technical endowment, Self-financing capacity, Investment per person employed

b. Dependent Variable: Profit size

The result is that most part of the total variance is generated by the regression equation.

In order to test the validity of multiple regression model a global test must be used, which researches whether all the independent variables have regression coefficients equal with zero, or in other words if the explained variance is not due to a random. The regression coefficients of the sample have as correspondents the following regression coefficients: β_1, β_2, β_3, β_4, β_5, Kulcsar, 2009. The alternative and null hypotheses are formulated as follows:

$H_0 = \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$

H_1 = not all β coefficients are equal to 0.

In order to test the null hypothesis we turn to F test that requires an analysis of the variance identified in the ANOVA table above. From the data in the previous table (Table 4) it can be ascertained that the value of the calculated F is 462.098 for the variance generated by the regression. The critical value of F, at the significance level of 0.05 with 5 degrees of freedom at numerator and 4 at denominator is 6.256. By comparing the values of F it results that it is compulsory to accept the alternative hypothesis, meaning that not all regression coefficients are equal to zero. This means that a significant influence of multiple regression model occurs over the dependent variables. The issue that arises now is to know which regression coefficients may be zero and which may not. It is imposed therefore to achieve an individual evaluation of the regression coefficients. It is compulsory to make an assessment the realization of a statistical test for each under the conditions where the null hypothesis states that each coefficient β is equal to zero and the alternative hypothesis states that these are different from zero Kulcsar, 2009.

The test used is the Student test, respectively t with n-(k+1) degrees of freedom Kulcsar, 2009. For each of the five variables, from the SPSS results, we get the calculated t values (Table 2). These are: 19.904 for self-financing capacity, 3.961 for return on equity, -4.232 for degree of technical endowment, -0.252 for investment per person employed and -0.977 for personnel cost per employee. In order to define the decision rule concerning the null hypothesis, the calculated t values will be compared with the critical value of t at a significance level of 0.05 in the case of a two-tailed test, with 10 – (5+1), meaning with 4 degrees of freedom. This value is ±2.776. The results are:

- In the case of self-financing capacity, calculated t (19.904) is higher than critical t (2.776). The level of significance indicated by the test 0.004 is lower than the chosen level of significance of 0.05. Therefore the null hypothesis is rejected and it is accepted that β_1 is different from zero.
- Looking at the return on equity, we can observe that calculated t (3.961) is higher that critical t (2.776). The null hypothesis is rejected and it is accepted that β_2 is different from zero.

- While observing the degree of technical endowment, we can see that the calculated t (-4.232) is lower than the critical t (-2.776). This means that the null hypothesis is rejected again, and it is accepted that β_3 is different from zero.
- Looking at the investment per person employed, we can observe that the calculated t (-0.252) is higher than the critical t (-2.776). This means that the null hypothesis is accepted and that β_4 is equal to zero.
- In the case of personnel costs per employee the calculated t (-0.977) is higher than the critical t (-2.776). This means that the null hypothesis is accepted and that β_5 is equal to zero.

Therefore it is considered that two of the variables: personnel costs per employee and the investment per person employed are not significant predictors for the dependent variable: profit size. In this case the regression model will no longer contain these variables. If we make the determinations for the new regression model, the results will be:

Table 5. Estimation of standard error deviation – Model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.998[a]	.997	.995	2451.846

a. Predictors: (Constant), Degree of technical endowment, Self-financing capacity, Return on equity

In this case the coefficient of determination R^2 is 99.70% (Table 5).

Table 6. Regression coefficients

Model		Unstandardized Coefficients		Standardized Coeff.		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-1373.986	2303.600		-.596	.573
	Self-financing capacity	.923	.025	.951	37.082	.000
	Return on equity	47.902	9.054	.172	5.291	.002
	Degree of technical endowment	-1.866	.515	-.112	-3.622	.011

a. Dependent Variable: Profit size

A new regression equation results from the above presented:

$\hat{y}$ = -1373.986 + 0.923 x_1 + 47.902 x_2 – 1.866 x_3

where: x_1 = self-financing capacity, x_2 = return on equity, x_3 = degree of technical endowment

Table 7. Analysis of variance - ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.085E10	3	3.617E9	601.750	.000[a]
	Residual	36069295.328	6	6011549.221		
	Total	1.089E10	9			

a. Predictors: (Constant), Degree of technical endowment, Self-financing capacity, Return on equity

b. Dependent Variable: Profit size

In Table 7 it can be observed that the value of the calculated F is 601.750 for the variance generated by the regression. The critical value of F, at the significance level of 0.05 with 3 degrees of freedom at numerator and

6 at denominator is 4.754. If we compare the values of F we can see that it is obligatory to accept the alternative hypothesis. This means that a significant influence of multiple regression model occurs over the dependent variables. Again we need to know which regression coefficients may be zero and which not. For this reason we achieved an individual evaluation of the regression coefficients.

4. Results

We could see that in the first regression model two of the independent variables weren't significant predictors for the profit size. For this reason we elaborated a new regression model. By performing the above mentioned tests, we found the following: using Student test, respectively t with n-(k+1) degrees of freedom, for each of the four variables we get the calculated t values (Table 6). We compared the calculated t values with the critical value of t at a significance level of 0.05 in the case of a two-tailed test, with 10 – (3+1), meaning with 6 degrees of freedom. This value is ±2,446. The results are the following:

- In the case of self-financing capacity, calculated t (37.082) is higher than critical t (2.446). The level of significance indicated by the test 0.004 is lower than the chosen level of significance of 0.05. Therefore the null hypothesis is rejected and it is accepted that β_1 is different from zero.
- In the case of the variable "return on equity" the calculated t (5.291) is higher than the critical t (2.446). Therefore the null hypothesis is rejected and it is accepted that β_2 is different from zero.
- If we look at the degree of technical endowment, we can observe that the calculated t (-3.622) is lower than the critical t (-2.446). Again the null hypothesis is rejected, and it is accepted that β_3 is different from zero.

From the data presented above we can draw the following conclusion: three of the performance indicators, namely the self-financing capacity, the return on equity and the degree of technical endowment are significant predictors for the dependent variable, namely the profit size, in the analyzed period 2002-2011.

With the method of multivariate analysis of dependencies we could find significant and powerful correlations between the independent variables. The most powerful correlation occurred between personnel costs per employee and investment per person employed (0.977). Other important correlations could be found between the self-financing capacity and investment per person employed (0.718) and between self-financing capacity and personnel cost per employee (0.692).

This analysis represents an important part of the PhD thesis. Future research will be performed by taking into consideration other variables. The final purpose of these studies is to find the most appropriate indicators which can be used in building up a mathematical model which corresponds to the growth of ceramic enterprises' performance.

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