APPLICATION OF THE REGRESSION MODEL IN DETERMINATION OF THE RELATION BETWEEN THE QUANTITY OF PRODUCTION, IMPORT, EXPORT AND AVAILABILITY OF ELECTRICAL POWER AND ITS FINAL CONSUMPTION IN CROATIA

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ABSTRACT

In the framework of promotion of energy efficiency and renewable energy sources in Croatia it is aiming at achieving the objectives of energy policy that includes sustainable energy development, energy supply security and competitiveness of energy systems. In order to make a final conclusion it is necessary to identify the key factors and by scientific evidence minimize conflicting opinions in the pricing of fuel, limiting climate change and the use of various forms of energy, the possibilities of import or export of energy, all in accordance with national interests. Although the consumption of electricity in Croatia is small, inefficient usage of electricity brings structure of its available resources into a state of exhaustion.

In the paper, but not entering in the structure of production and consumption, by applying regression models, the relationship between the amount of production, imports, exports and the availability of electricity to its final consumption in the Republic of Croatia is determined. Descriptive statistical analysis in this paper is reduced to the determination of the analytical expression that in some sense the best presents empirical data on the variables shown for comparison. By simple linear regression model and multiple regression model the relationship between production, import and export of electricity are represented i.e. the total availability and its consumption. Based on obtained size it will be determined whether and in how much regression model is representative. The calculated parameters have provided a clear picture about the relationship between studied variables.

JEL Classification: C61, H42

Keywords: regression analysis, production, import, export and availability, consumption of electricity

INTRODUCTION

Energy efficiency is not observed as energy savings. Saving always entails certain sacrifices, while the efficient use of energy never violate the conditions of work and life. In addition to concerns about their own environment a precondition for economic and social development is also to meet energy demand, which is influenced by various factors such as population growth, increasing living standards of far less developed regions, the increase of modernization in agriculture and other factors. The problem of energy efficiency can reduce intersectoral measures proposed by national program of energy efficiency 2008th - 2016th (NPEU: 26). For this reason, an analysis of the availability of electricity in terms of domestic production, imports and exports and total final energy consumption was done. One of the possibilities is the usage of regression models. With the assumed linear relationship of production, import and consumption of electric energy, in this paper, a simple linear regression model has been used, and the analysis is extended to the multiple regression models to verify the representativeness of the applied models.

THE DATA USED

The paper used secondary data on production, import and export of electricity and its consumption published on the official website of Croatia Bureau of Statistics. The data presented in Table 1 represent the variables used in the regression analysis.

Table 1 Production, import and export of electricity and its consumption, GWh

	Total gross production*	Imports*	Total gross production + Imports	Exports*	Final consumption*	Available for internal market	Transmission and distribution losses*
	1	2	3=1+2	4	5	6=1+2-4	7
2002.	12.725	3.923	16.648	792	13.132	15.856	2.077
2003.	13.248	4.499	17.747	1.142	13.416	16.605	2.543
2004.	13.976	5.339	19.315	2.296	14.163	17.019	2.224
2005.	13.140	8.802	21.942	4.323	14.923	17.619	2.131
2006.	13.037	8.374	21.411	3.306	15.512	18.105	1.909
2007.	12.462	7.926	20.388	1.948	15.831	18.440	2.027
2008.	12.616	8.249	20.865	2.140	16.545	18.725	1.706
2009.	13.149	7.651	20.800	2.578	15.915	18.222	2.019
2010.	14.669	6.784	21.453	2.712	16.248	18.741	2.022

Source: *Statistical Yearbook of the Republic of Croatia 2012, Croatia Bureau of Statistics, p. 303

In this case we used total gross electricity production instead of net electricity production. Gross electricity production is the sum of the electrical energy production by all the generating sets concerned measured at the output terminals of the main generators. Net electricity production is the electrical energy supplied from a power station to a power-supply grid and it represents the difference between electrical energy produced in a generator and own supply. To ensure the required quantity of net electricity production it is necessary to include the amount of energy used by generators for their consumption.

APPLICATION OF REGRESSION ANALYSIS

In order to determine the relationship between the production, import and export of electricity and related to these variables total available electricity generation and consumption in Croatia, the paper used regression model. To determine, by using the regression model, analytical expression of certain features that represents the relationships between the variables paper used descriptive statistics in order to estimate the unknown parameters.

According to Šošić (2006: 384) from the perspective of statistical analysis model is linear if it is linear in the parameters. About linearity of the model and solving multiple equations with multiple unknowns wrote Proskuryakov (1978: 15). By simple linear regression model we are expressing analytically statistical relationship between the two phenomena. Simple linear regression model is:

$$y_i = \alpha + \beta x_i + e_i, i = 1,2,....., n \tag{1}$$

As α and β are unknown, it was determined that a and b are estimated parameters, and estimation of unknown variables e are equal the u_i. Then a linear regression model is with the estimated parameters:

$$y_i = a + bx_i + u_{i,}, 1 = 1,2,...., n \tag{2}$$

$$\hat{y}_i = a + bx_i \quad \text{– regression values} \tag{3}$$

$$u_i = y_i - \hat{y}_i \quad \text{– residual deviation} \tag{4}$$

Residual discrepancies are the basis for assessing the representativeness of the regression. By using it helps to calculate the variance and standard deviation of the regression. (Šošić, 2006: 394). Using them will judge the quality of the model.

In order to estimate the parameters the method of least squares was used. Minimizing the sum of squares of residual differences it is possible to get the expression for parameter estimation:

$$a = \overline{y} - b\overline{x} \tag{5}$$

$$b = \frac{\sum_{i=1}^{n} x_i y_i - n\overline{x}\overline{y}}{\sum_{i=1}^{n} x_i^2 - n\overline{x}^2} \tag{6}$$

In order to determine the representativeness of the regression we start from the expression:

$$\sum_{i=1}^{n}\left(y_i - \overline{y}\right)^2 = \sum_{i=1}^{n}\left(\hat{y}_i - \overline{y}\right)^2 + \sum_{i=1}^{n}\left(y_i - \hat{y}_i\right)^2 \tag{7}$$

or developed expression

$$\sum_{i=1}^{n} y_i^{\,2} - n\overline{y}^2 = \left[a\sum_{i=1}^{n} y_i + b\sum_{i=1}^{n} x_i y_i - n\overline{y}^2\right] + \left[\sum_{i=1}^{n} y_i^{\,2} - a\sum_{i=1}^{n} y_i - b\sum_{i=1}^{n} x_i y_i\right] \tag{8}$$

$\sum_{i=1}^{n}\left(y_i - \overline{y}\right)^2$ – total sum of squares (9)

$\sum_{i=1}^{n}\left(\hat{y}_i - \overline{y}\right)^2$ – interpreted sum of squares (10)

$\sum_{i=1}^{n}\left(y_i - \hat{y}_i\right)^2$ – unexplained sum of squares or the sum of squares of residual deviations (11)

The sum of squares allows calculation of representation indicators, which include measures of dispersion: standard deviation and coefficient of regression variation and standard measure of the representativeness of the regression models, the coefficient of determination.

$$\sigma_{\hat{Y}} = \sqrt{\frac{\sum_{i=1}^{n} y_i^{\,2} - a\sum_{i=1}^{n} y_i - b\sum_{i01}^{n} x_i y_i}{n}} \tag{12}$$

– Standard deviation of the regression (Std Dev)

$$V_{\hat{y}} = \frac{\sigma_{\hat{y}}}{\overline{y}}100 \tag{13}$$

– Coefficient of variation regression

$$r^2 = \frac{a\sum_{i=1} y_i + b\sum_{i=1} x_i y_i - n\overline{y}^2}{\sum y_i^{\,2} - n\overline{y}^2}, 0 \le r^2 \le 1 \tag{14}$$

– Coefficient of determination

Square root of the coefficient of linear determination gives the linear correlation coefficient, or Pearson's correlation coefficient, which determines the strength and direction of the relationship, a sign of him is the same as the regression coefficient *b*.

$$r = \sqrt{\frac{\sum_{i=1}^{n}(\hat{y}i - \hat{y})^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2}}, -1 \le r \le 1 \quad \text{– Linear correlation coefficient} \quad (15)$$

CALCULATION OF INDICATORS

Studying the officially published data (CBS, 2012: 303) the need was recognized to determine the connection between the production, import and export of electricity and its consumption, i.e. determination of model that will be able to describe the relationship between these variables. Following the economic logic it is assumed that between the variables exist the linear statistical relationship and during the analysis simple linear regression model has been applied. Pairs of variables are presented in two tables, where x is independent and y the dependent variable. Substitution of variables changes result only in a part of measures of dispersion. After tested relationship between the variables, shown in Table 2, the results are non-representative, and in Table 3 are representative model of a simple linear regression.

Table 2: Results for non-representative simple linear regression model

Relation 1		***Relation 2***		***Relation 3***		***Relation 4***	
Total gross producti-on	Imports	Total gross producti-on	Exports	Total gross producti-on	Final consumpti-on	Total gross production	Available for internal market
x_i	y_i	x_i	y_i	x_i	y_i	x_i	y_i
12.725	3.923	12.725	792	12.725	13.132	12.725	15.856
13.248	4.499	13.248	1.142	13.248	13.416	13.248	16.605
13.976	5.339	13.976	2.296	13.976	14.163	13.976	17.019
13.140	8.802	13.140	4.323	13.140	14.923	13.140	17.619
13.037	8.374	13.037	3.306	13.037	15.512	13.037	18.105
12.462	7.926	12.462	1.948	12.462	15.831	12.462	18.440
12.616	8.249	12.616	2.140	12.616	16.545	12.616	18.725
13.149	7.651	13.149	2.578	13.149	15.915	13.149	18.222
14.669	6.784	14.669	2.712	14.669	16.248	14.669	18.741

∑119.022	∑61.547	∑119.022	∑21.237	∑119.022	∑135.685	∑119.022	∑159.332
a	13642,19	a	-2057,46	a	13933,29	a	11947,22
b	-0,514	b	0,334	b	0,086	b	0,072
Std Dev	1674,57	Std Dev	980,29	Std Dev	1171,81	Std Dev	654,76
V	24,49%	V	41,54%	V	77,73%	V	4,95%
r2	0,0393	r2	0,0479	r2	0,0024	r2	0,0109
r	-0,1983	r	0,2189	r	0,0485	r	0,1045

Table 3: Results of representative models of simple linear regression

Relation 5		***Relation 6***		***Relation 7***		***Relation 8***	
Final consum-ption	Imports	Available for internal market	Final consum-ption	Total gross production + Imports	Available for internal market	Final consum-ption	Total gross production + Imports
x_i	y_i	x_i	y_i	x_i	y_i	x_i	y_i
13.132	3.923	15.856	13.132	16.648	15.856	13.132	16.648
13.416	4.499	16.605	13.416	17.747	16.605	13.416	17.747
14.163	5.339	17.019	14.163	19.315	17.019	14.163	19.315
14.923	8.802	17.619	14.923	21.942	17.619	14.923	21.942
15.512	8.374	18.105	15.512	21.411	18.105	15.512	21.411
15.831	7.926	18.440	15.831	20.388	18.440	15.831	20.388
16.545	8.249	18.725	16.545	20.865	18.725	16.545	20.865
15.915	7.651	18.222	15.915	20.800	18.222	15.915	20.800
16.248	6.784	18.741	16.248	21.453	18.741	16.248	21.453
∑135.685	∑61.547	∑159.332	∑135.685	∑180.569	∑159.332	∑135.685	∑180.569
a	-11174,33	a	-6406,02	a	8015,61	a	1640,05
b	1,195	b	1,213	b	0,4829	b	1,222
Std Dev	976,78	Std Dev	191,80	Std Dev	481,78	Std Dev	922,52
V	14,28%	V	1,27%	V	2,72%	V	4,60%
r2	0,6731	r2	0,9733	r2	0,7449	r2	0,7072
r	0,8204	r	0,9865	r	0,8631	r	0,8409

The results in Table 2 and 3 shows the estimated parameters *a* and *b* required for the interpretation of the regression equation. The parameter *a* is the value of the regression function for the value of the independent variable that is equal to zero. Negative sign of the parameter *a* does not change the interpretation. Such a regression model is similar to the model that examines the relationship between supply and price, which is with the mathematical term described in the book of Chaing (1994: 37) which gives the answer and graphical representation for the case where the intersection with the vertical axis negative: "If we assume that the cross section is negative, we achieve that the supply curve has a positive intersection with the horizontal axis and thereby meets previously seated condition that there is no supply until the price is not positive and high enough." The regression coefficient *b* shows how the linear average of GWh changes the value of the dependent variable y if the independent variable increases by 1 GWh of electricity.

Results of representation indicators, standard deviation and variance σ and variance V, well enough describe the model and the coefficient of determination r^2. As shown in Table 3 their low values show that the average and the percentage deviation of the actual values of regression very small. The value of the coefficient of determination r^2, closer to 1 than 0 shows the proportion of the interpreted sum of squares in the total sum of square has big deviations. For this reason, we say that the models in Table 3 are representative, as in the model in Table 2 not the case.

The calculate Pearson's correlation coefficient *r* shows within the representative model, according to Chadockovoj scale or Roemer-Orphal scale strong and positive correlation between the variables *x* and *y*, while the non-representative models indicate a weak correlation.

With the aim of informing about consumption, and in connection with this and production, imports and total consumption of electricity in the Republic of Croatia and the export of electricity, there is a need to verify the relationship between those variables. Given the assumed linear relationship between them it is approached to the examinations of simple linear regression models. Starting from the economic logic of the relation between these variables, relation should be linear and closely linked. In the relationship of certain variables that assumption proved to be correct as the relationship between final consumption and imports, available for internal market and final consumption, total gross production including imports and available for internal market, total final consumption and gross production including imports. Contrary to such relation conclusion did not provide data on the relation between the total gross production and final consumption and the relation between total gross production and available electricity for internal electricity market, relation 3 and 4. There has been an attitude 7 in Table 3 where total gross production and imports have close and positive relation with the availability of electricity. In Table 3 relation 8 says that with increasing 1 GWh of final consumption, total gross production with included imports growing for 1.222 GWh of electricity, which is almost entirely attributable to the importation. It was concluded in relation to 5 where 1 GWh of electricity final consumption causes an increase in imports of 1.195 GWh. The question is why it is not 1: 1. The reason is the export and transmission and distribution losses, presented in Table 1 and the cost of electricity production, which is not shown in this paper. It is further linked with relation 6 to which availability for internal market have close and positive relation with the final consumption of electricity. Although the export of electricity from the Croatian is present that has a positive relation with the total production, its impact on the availability of electrical power according to the results is present, but not crucial, noting that the model is not representative, as shown in Table 2 relation 2.

In accordance to the presented data the export variable ensures linearity of availability and final consumption. Beside simple regression analysis of indicator variables that is explained in detail by Newbold et. al. (2010: 512, 542) it is possible to extend the analysis by using multiple linear regression model, which is presented in detail by Šošić (2006: 445) and for which it is said to be the basic regression model. This model is used for analytical presentation of co variation of many phenomena, and in addition a bigger number of variables in a nonlinear model belong to the group of linear models, which are analyzed in the same way as a multiple linear regression model.

Multiple linear regression models was used to check if it affects overall production and final consumption of electricity, as independent variables, to the import of electricity, the dependent variable. For this analysis the data from Table 1 were used. In the analysis we start from linear regression model for *n* values:

$$y_i = \alpha + \beta_{1x} + \beta_2 x_{i2} + e_i . i = 1,2,....,n \tag{16}$$

Estimates of the parameters α, β1 and β2 is performed by using method of the least squares, i.e. estimation of parameters is the solution of the system of three linear equations with three unknowns, since in the analysis we have two independent variables, K = 2. Solution of the equations gave estimates of the parameters:

α=3240,05, β_1 =0,6197 i β_2=1,2216

Regression model with the parameters is as follows:

$$\hat{y} = 3240{,}05 - 0{,}6197x_1 + 1{,}2216x_2$$

The obtained result confirms what has previously concluded that the import is variable that regulates the state of the electricity market in Croatia because the import of electricity is reduced by 0.6197 GWh of electricity, if the total gross production increases by 1Gwh, and it increases to 1.2216 GWh, if the final consumption of electricity increases by 1GWh.

CONCLUSION

All the above analysis was conducted with the aim of insight into the relation of available electricity and consumption. In order to bring a correct conclusion in the analysis are included other variables that directly affect the relation between availability and consumption. Analysis, in addition to domestic production encompassed both import and export. The result showed that the import is variable that provides sufficient electricity supply on the Croatian market. But as energy efficiency means using less power, the level of imports or their own power generation can be reduced. On the other hand, the increasing availability of energy, wider opportunities for energy resources and energy at affordable prices is a key precondition for economic and social development in all societies. In addition to financial savings, reduced energy consumption should be viewed from the point of quality of our own environment. Of course, that level of available electricity must be seen in the rate of population growth or decline, production of new and better machine consumers who work with small consumption of electricity and in the awareness of citizens about the importance of savings. Furthermore there is still the current structure of the electricity to be revised as well as possibilities of switching to other forms of energy. Relations between different energy sources and in the total availability in this paper unfortunately are not analyzed although the setting of these correlations would show interesting results.

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