EVALUATION OF FACTORS AFFECTING BROADBAND INTERNET ACCESS USING REGRESSION ANALYSIS

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Abstract

In this paper the multiple linear regression analysis is performed in order to determine factors with the greatest impact on the implementation of the broadband Internet access. The data observed in the study were the available official secondary data for 2010 and the 27 countries of the European Union and Croatia as a potential future member of the EU. Since the broadband Internet access is usually measured with the broadband penetration rate, the broadband penetration rate is selected as the dependent variable in the model. Using the stepwise least squares forward selection method three of the six analysed explanatory variables are recognised as significant. The selected model includes the following explanatory variables: the percent of urban population, frequent users of the Internet and the price of local loop unbundling in the gross national income. The model passes all diagnostics tests.

Keywords: broadband Internet access, multiple linear regression, multicollinearity, Box-Ljung autocorrelation test, White's heteroskedasticity test, Jarque-Bera test

1 INTRODUCTION

The aim of this paper is the use of the regression analysis for identifying variables that significantly affect the variation of the broadband Internet access. By recognizing these variables and with an effective impact on their movements it is possible to influence the development of the broadband Internet access, and thus the development of the economy as a whole (see [9], [10], [11] and [13]). The broadband Internet access is the communications network approach that enables the user to transfer data given at the lowest speed with the possibility of a permanent connection to the Internet. It is usually measured with the broadband penetration rate, which indicates the percentage of broadband connections per capita. This variable is considered to be a dependent one, and information on it is taken from the [7] for January 1st, 2011, and the sources of independent variables data are [6] from 2011 and [8]. Various studies that have dealt with the broadband Internet access have shown that it affects the increase in the gross domestic product and that enhancing its use increases the efficiency of various branches of an economy.

2 CURRENT STATE OF BROADBAND INTERNET ACCESS IN THE EUROPEAN UNION

When the term "broadband" was first introduced it was a sign the difference compared to a dial-up Internet access and with respect to two distinct characteristics: speed and constant always-on connection, compare to [3]. Therefore the broadband internet access is usually considered approach to communication network that allows the user to transfer data with a certain minimum speed capability of the always on Internet connection. According to the EUROSTAT definition, [7], the considered broadband Internet access incoming downstream speeds of 144 kbit/s, while the International Telecommunication Union (ITU) and the Organization for Economic Cooperation and Development (OECD) consider the broadband speed of 256 kbit/s. However, it is expected that these limits will move in the future due to the growing need for increasing capacity.

Broadband Internet access is generally defined as a set of technologies that allow the exchange of large amounts of data at high speeds through the stationary (fixed) and mobile (cellular) connections / networks[1]. Users who access the Internet via broadband apply the Internet more frequently and for a greater variety of activities comparing to individuals who access the Internet through dial-up or narrowband port, compare to [13].

But, broadband Internet access is necessary to define the general minimum achievable speed Internet access, and regarded it as an ecosystem consisting of infrastructure, services, content, and end-users as it is for its effective development must simultaneously develop all of these segments. The key is to create an enabling environment for the growth on the supply side through access to networks and services - but it is also important to enable the demand for broadband Internet access, see in [10].

Information and communication technologies, as well as electricity, can be regarded as a general purpose technology whose characteristics permeation through the entire economy and society, the continuous development and progress and inducing innovation[2]. Broadband networks are increasingly essential part of the global information society by facilitating the overall economic growth, create jobs, encourage innovation and promote national competitiveness[3]. The development of broadband networks is crucial for the 21st century as the 19th century was the construction of railways and telephone connection in the 20th century.

Broadband Internet access brings new opportunities and benefits to end users. Facilitating access to higher-speed and constant always on connection, broadband access, compared with narrowband access, allows the exchange of richer content, faster and more advanced communication. A broadband internet contributes to an economy by creating information society, and it encourages innovation and the development of the economy and attracts foreign investment. Also, the scope for new applications and services that will attract end-users to use broadband internet access will contribute to the realization of return on investment in broadband infrastructure development[4]. Specifically, the broadband connection itself provides no value or service. Only online services and applications via broadband connections (such as *Voice over Internet Protocol* - VoIP services, video conferencing, video on demand and other information society services) create benefits to the end user.

The contribution of broadband Internet access is reflected in the increase of efficiency in areas such as education, health, public administration, science, tourism, agriculture, and to encourage the development of less populated regions. Previous research indicates the importance of broadband as a driver of economic development, proving the impact of broadband on the increase in gross domestic product and job creation.

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[1] Florence School of Regulation (2011) Broadband Diffusion: Drivers and Policies. Fierce: Florence School of Regulation, p. 10.

[2] info DEV/ITU (2012) ICT regulation toolkit: Module 4

[3] Intel (2008) *The Economic Impact of Broadband: Best practices enable developing nations to reap economic benefits of broadband*. United States: Intel

[4] International Telecommunication Union (ITU) (2003) *Promoting broadband: background paper for workshop on promoting broadband*. Geneva: ITU, p 3.

According to a study from 2008, which was prepared for the European Commission consultant Micus Management Consulting GmbH [11], building broadband access infrastructure, high levels of education, and the use of services provided through the Internet and promoting innovation are four main strategic guidelines for promoting economic impact of broadband Internet access in Europe. According to the survey, depending on the growing use of value added online services provided over the Internet, there are three cases:

- in the base case[5], the development of broadband Internet access contributes to the opening of 1.076 million jobs and increase the gross domestic product of 849 billion euros in the period since 2006 to 2015,

- in the best case[6], the development of broadband Internet access contributes to the opening of 2.112 million jobs and increase gross domestic product by 1080 billion in the period since 2006 to2015,

- in worst case scenario[7], the development of broadband Internet access, help provide 345,000 jobs and increase the gross domestic product of 636 billion euros in the period since 2006 to 2015.

Group by Czernich et al. [4] is based on data for the OECD countries and found a significant effect of introduction and spread of broadband Internet growth in gross domestic product per capita. The Gross Domestic Product per capita is on average 2.7 to 3.9 percent higher after introducing the broadband internet. Furthermore, increasing the density of broadband connections by 10 percentage points increases the annual growth rate of gross domestic product per capita of 0.9 to 1.5 percentage points.

Given the recognized importance of broadband as a driver of growth of the economy and society as a whole, a number of states made a strategic commitment to increasing broadband access and promoting broadband services.

Digital Agenda for Europe [6], one of the seven initiatives Europe 2020 Strategy, aimed at achieving sustainable economic and social benefits from a digital single market based on speed (broadband) internet. One of the objectives of the Digital Agenda refers to the availability of broadband access, and specifies that 100% of the population of the European Union by 2013. The must have basic access, and 2020. The 100% of the population of the European Union must have quick access to a network of 30 Mbit / s or more, and 50% of households have access to ultrafast than 100 Mbit / s or over.

3 ANALYSIS

This study uses the available secondary data for the 27 countries of the European Union and Croatia as a potential future member of the EU. The data refer to 2010.
Explanatory variables for the purpose of the regression analysis of the broadband penetration rate are variables which, based on past research (see [11] and [12]), have shown the impact on relevant variations of the broadband Internet access.
The linear regression model with six independent variables was analyzed.
The dependent variable in the model is BBPR (broadband penetration rate), and the following variables are chosen as explanatory:

GNIpc =Gross National Product per Capita in US$
URBPOP= the percent of urban population
INT_USE =individuals who use the Internet regularly (every day)

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[5] The base case assumes a constant rate of growth in the use of value added services provided over the Internet by 2015 year, which is equal to the European average in the period since 2004 to 2006 year, ranging from 3%.
[6] Best case involves a progressive increase in the rate of use of value added services provided over the Internet by 2015 at the average rate on the level of use that in the period since 2004 to 2006 year had the most developed European countries.
[7] The worst case involves a progressive decline in the use of value added services provided over the Internet by 2015 at the average rate of the level of use that in the period since 2004 to 2006. held the weaker European countries.

COMP = the percent of households with a computer access
PRICE = the retail price of the broadband Internet access (fixed BB basket percent of GDPpc)
P_LLU = the percent of the wholesale price of broadband Internet access services (services unbundled access to the local loop) of GNIpc.

3.1 Model selection and Parameter Estimation

The linear regression model is fitted by the stepwise least squares forward selection method.This method begins with no variables in the model. For each of the explanatory variables, this method calculates F statistics that reflect a variable's contribution to the model if it is included. The p-values for these F statistics are compared to the 0.05 significance level for including a variable in the model. Slovakia is omitted from the estimated model due to a large residual (large values of Cook's D influence statistics) and due to a large value of the standard influence of this observation on the predicted value (DFFITS) in the model with the 28 countries. Using the software package SAS Enterprise Guide 4.3 the following results (in Table 1) were obtained.

Table 1. shows explanatory variables entered into the model. The first variable entered into the model is INT_USE which exhibits the highest correlation with the dependent variable (the partial coefficient of determination is 0.7895). The second regressor included in the model is the variable URBPOP, and the last one is the variable P_LLU.

No other variable met the 0.05 significance level for entry into the model. Table 1 also presents the coefficient of determination and Mallow's C (p) statistic for each regression model (with one, two, or three regressor variables), as well as F-statistics and the associated p-values calculated for each explanatory variable included in the model.

Table 1. Summary of Forward Selection

Step	Variable Entered	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	INT_USE	1	0.7895	0.7895	13.1334	93.77	<.0001
2	URBPOP	2	0.0591	0.8486	4.9910	9.37	0.0054
3	P_LLU	3	0.0342	0.8828	1.1264	6.70	0.0164

”Figure 1.” graphically presents the relevant criteria for the selection of the best linear regression model. It shows that according to all criteria, the model with three regressor variables is the best model. For the final model selected in three steps, the coefficient of determination and the adjusted coefficient of determination are the largest (Adjusted R-Square = 0.8675), while other indicators (Mallow's C (p), Akaike Information Criterion AIC, the Bayesian Information Criterion BIC and Schwarz Bayesian Information Criterion SBC value) for that model take a minimum value.

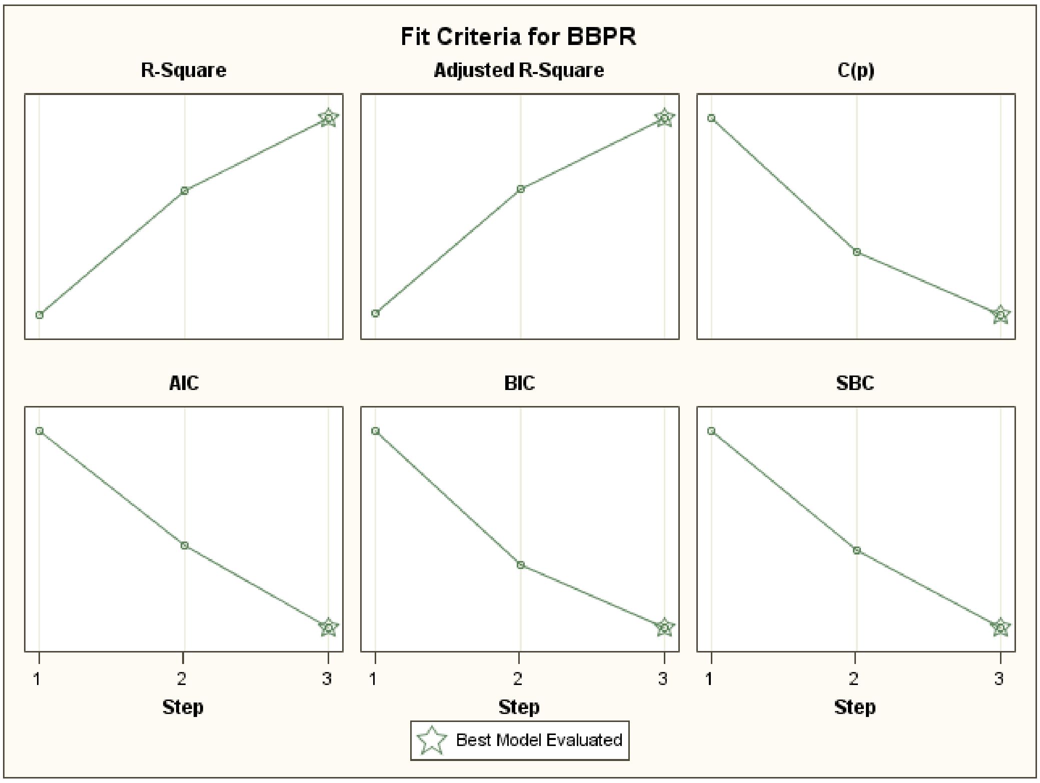

Figure 1. Fit criteria for the broadband penetration rate

The first four columns of Table 2. list three sources of variation, associated *degrees of freedom,* and the associated sum of squares for each source of variation, and mean squares, which are the sum of squares divided by their associated degrees of freedom. The empirical F-ratio, calculated by dividing the model mean square by the error mean square, as well as measures of the representation of the model are presented. The F-test (a test for significance of regression) shows that the regression is significant at a significance level less than 1%.

Table 2. The Analysis of Variance report

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	1053.60259	351.20086	57.72	<.0001
Error	23	139.93848	6.08428		
Corrected Total	26	1193.54107			

The summary of the Fit report in Table 3 provides the standard error of the estimate (Root MSE). It is the standard deviation of the errors about the regression, and the estimated value is 2.46663 index points. The Coefficient of Variation, the related relative measure of dispersion of the errors about the regression takes value 9.80%, which indicates a good representation of the model. The adjusted coefficient of determination is 0.8675.

Table 3. The summary of the Fit report

Root MSE	2.46663	R-Square	0.8828
Dependent Mean	25.16222	Adj R-Sq	0.8675
Coeff Var	9.80292		

Table 4. contains LS parameter estimates of the selected model (see [1] and [5]), the associated standard errors, the corresponding t-ratios and the associated p-levels, variance inflation factors and interval estimates of parameters.

Table 4. Parameter Estimates Report

Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate	Variance Inflation	95% Confidence Limits	
Intercept	1.09262	3.40355	0.32	0.7511	0	0	-5.94817	8.13340
URBPOP	0.17160	0.04789	3.58	0.0016	0.30896	1.45840	0.07253	0.27067
INT_USE	0.26188	0.04665	5.61	<.0001	0.57840	2.08276	0.16537	0.35838
P_LLU	-2.84404	1.09859	-2.59	0.0164	-0.23102	1.56211	-5.11665	-0.57144

The selected regression model is:

$$\hat{y} = \underset{(3.40355)}{1.09262} + \underset{(0.04789)}{0.17160}\text{URBPOP} + \underset{(0.04665)}{0.26188}\text{INT\_USE} - \underset{(1.09859)}{2.84404}\text{P\_LLU} \quad (1)$$

The first regression coefficient is $\hat{\beta}_1 = 0.1716$. It means that if the urban population is increased by 1 index point, assuming that the other two regressors are held constant at a certain value, BBPR increases by 0.716 index points on average. Similarly if INT_USE increases by 1 index point, holding the other regressor variables constant at a fixed level, BBPR increases by 0.26188 index points on average. If P_LLU increases by 1 index point, and other regressors are held at a fixed level, BBPR is reduced by 2.84404 index points on average.

The fourth column of Table 4. presents t-statistics (t Values). It can be seen that each explanatory variable in the model is significant at the 5% significance level, because the corresponding empirical significance levels, denoted as p-values, are less than 0.05.
To determine the relative impact of the independent variables on the dependent variable in the model the standardized regression equation8 should be analyzed:

$$\hat{y}^* = 0.30896 URBPOP^* + 0.57840 INT\_USE^* - 0.23102 P\_LLU^* \quad (2)$$

Standardized coefficients refer to how many standard deviations a dependent variable will change per standard deviation increase in the predictor variable. Equation (2) shows that the variable INT_USE has the greatest impact on BBPR. If INT_USE increases by one standard deviation, holding the other regressor variables constant at a fixed level, BBPR increases by 0.5784 standard deviation on average.

3.2 Multicollinearity

Furthermore, Table 3 shows Variance Inflation Factors (VIF), which are indicators of multicollinearity[9].
The VIF is defined:

$$VIF_i = \frac{1}{1-R_i^2} \quad (3)$$

[8] Standardised regression coefficients are calculated to compare the relative importance of different variables. Regression equation (2) is estimated for standardized variables: $y_i^* = \frac{y_i - \bar{y}}{\sigma_y}$, and similarly URBPOP*, INT_USE* and P_LLU* are standardized variables associated to the variables URBPOP, INT_USE and P_LLU.
[9] The multicollinearity problem is present if the two or more variables are approximately linearly dependent (including the variable $X_0 = 1$), which generates a constant term.

where R_i^2 is the coefficient of multiple determination for the regression of the i-th explanatory variable as a function of the other explanatory variables. Given that:

$$VIF_i < 5 \ \ for \ \ i = 1,2,3$$

it can be concluded that there is no multicollinearity problem.
The last two columns of Table 4. state the limits of 95% interval estimates of parameters. For example, the interval parameter estimate of β_2 is:

$$P\{0.16537 \le \beta_2 \le 0.35838\} = 0.95 \tag{4}$$

Equation (4) shows that if the variable INT_USE increases by one index point, holding other regressors at a fixed level, BBPR with the confidence 0.95 will increase between 0.16537 and 0.35838 index points on average.

3.3 Autocorrelation and the partial autocorrelation function

The remainder of the initial assumptions about the linear regression model should also be examined. In the linear regression model it is assumed that error terms $\{\varepsilon_t\}$ are mutually independent and that they are identically distributed normal random variables with a constant variance.

If the assumption of independence of random variables is not met, there is the problem of autocorrelation.[10]

In order to examine the autocorrelation problem the Box-Ljung test was performed. The null hypothesis says that there is no autocorrelation up to order k (i.e., that all the autocorrelation coefficients equal to zero, and that the process $\{\varepsilon_t\}$ is a pure stochastic process or "the white noise":

$$H_0 : \rho_1 = \rho_2 = \cdots = \rho_k = 0 \tag{5}$$
$$H_1 : \exists \rho_j \ne 0, \ j = 1,2,\ldots,k$$

Sample: 1 27
Included observations: 27

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.134	0.134	0.5402	0.462
		2	-0.074	-0.094	0.7119	0.700
		3	0.088	0.115	0.9673	0.809
		4	-0.018	-0.057	0.9779	0.913
		5	-0.034	-0.004	1.0190	0.961
		6	-0.208	-0.228	2.6264	0.854
		7	-0.291	-0.240	5.9335	0.548
		8	-0.099	-0.083	6.3340	0.610
		9	-0.007	-0.001	6.3360	0.706
		10	-0.155	-0.151	7.4384	0.684
		11	-0.133	-0.134	8.2979	0.686
		12	0.255	0.225	11.687	0.471

[10] Autocorrelation or serial correlation is the name for the correlation of random variables within a stochastic process.

Figure 2. Correlogram of residuals

"Figure 2.", obtained using the software package EViews6, presents the autocorrelation (ACF) and the partial autocorrelation function (PACF) of the residuals, Q-statistics for lag k ≤ 12, and the associated empirical significance levels (denoted by PROB). The autocorrelation coefficient estimates (and the partial autocorrelation coefficient estimates) do not differ significantly from zero. The hypotheses of the Box-Ljung test for lag k=12 are:

$$H_0: \rho_1 = \rho_2 = \cdots = \rho_{12} = 0$$
$$H_1: \exists \rho_j \neq 0,\ j = 1,2,\ldots,12$$

whereby the test statistics Q_{12}=11.687, and the corresponding p-value= 0.471. It can be concluded that at the significance level 5% (or 1%) there is no autocorrelation problem for all lags k≤ 12.

3.4 Heteroskedasticity

Heteroskedasticity is present (see [1]) when the assumption of invariance of the variance of random variables $\{\varepsilon_t\}$ in a linear regression model is violated. In this paper, White's heteroskedasticity test is performed. This test is one of the maximum likelihood tests. The null hypothesis of the test assumes homoskedasticity against heteroskedasticity of an unknown, general form. The test is performed by comparing the LS estimated variances in the case of homoskedasticity and heteroskedasticity. Assuming homoskedasticity, the difference between the obtained estimates would be insignificant. White's test is performed in two steps. In the first step residuals of the initial regression model are calculated. The second step calculates the auxiliary regression equation in which the values of the dependent variables are squares of residuals of the main regression while explanatory variables are explanatory variables from the initial model. It also calculates the squares of them and their cross products. Test statistics is nR^2, where n is the sample size, and R^2 is the coefficient of determination of auxiliary regression. The nR^2 statistics is asymptotically distributed according to the $\chi^2(r)$ distribution, where *r* equals the number of explanatory variables in auxiliary regression.

Table 5. presents the results of White's test for the estimated auxiliary regression obtained using the software program Eviews6. Since the test statistics nR^2 (Obs*R-squared) is 8.369095 and the associated p-value is 0.4974, it is concluded that there is no heteroskedasticity problem.

Table 5. Heteroskedasticity Test: White

F-statistic	0.848498	Prob. F(9,17)	0.5845
Obs*R-squared	8.369095	Prob. Chi-Square(9)	0.4974
Scaled explained SS	3.249865	Prob. Chi-Square(9)	0.9536

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Sample: 1 27
Included observations: 27

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-43.78423	90.82321	-0.482082	0.6359
URBPOP	0.709695	1.847761	0.384084	0.7057
URBPOP^2	-0.010180	0.007149	-1.424096	0.1725
URBPOP*INT_USE	0.014989	0.020119	0.745014	0.4664
URBPOP*P_LLU	-0.202954	0.921261	-0.220300	0.8283
INT_USE	0.594590	1.326038	0.448396	0.6595
INT_USE^2	-0.012608	0.013672	-0.922170	0.3693
INT_USE*P_LLU	-0.378797	0.680130	-0.556947	0.5848

P_LLU	33.74170	42.89830	0.786551	0.4424
P_LLU^2	-1.933378	6.720674	-0.287676	0.7771

R-squared	0.309966	Mean dependent var	5.182907
Adjusted R-squared	-0.055345	S.D. dependent var	5.464029
S.E. of regression	5.613197	Akaike info criterion	6.566235
Sum squared resid	535.6356	Schwarz criterion	7.046175
Log likelihood	-78.64417	Hannan-Quinn criter.	6.708946
F-statistic	0.848498	Durbin-Watson stat	1.520127
Prob(F-statistic)	0.584471		

Whether the error terms are normally distributed as is assumed in the model needs to be investigated.

3.5 Jarque-Bera test

“Figure 3.”, obtained using the software package EViews6, displays a histogram and descriptive statistics of the residuals, including the Jarque-Bera statistic for testing normality. Jarque-Bera test, which uses the LS estimates of the coefficient of skewness and the kurtosis coefficient of residuals, examines whether the estimated values differ significantly from the values of these measures for the normal distribution. Jarque-Bera is defined as follows:

$$JB = \left[\frac{\alpha_3^2}{6} + \frac{(\alpha_4 - 3)^2}{24} \right] \tag{6}$$

Assuming normality, JB belongs to the chi-square distribution with 2 degrees of freedom. In the analyzed model JB=1.016416, and the associated p-value is 0.601573. The Jarque-Bera statistic is not significant. The null hypothesis which assumes normality is not rejected.

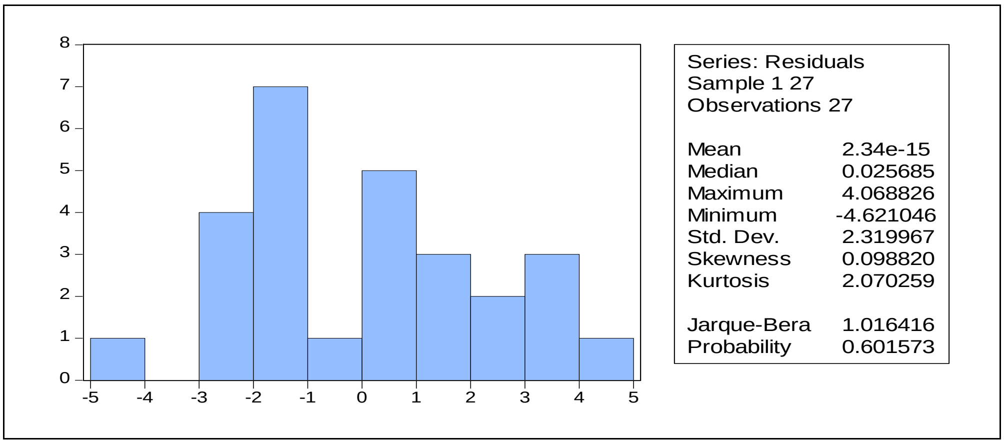

Figure 3. The histogram, descriptive statistics of the residuals and Jarque-Bera statistics

4 CONCLUSION

Due to the great significance of the broadband Internet access, variables which significantly affect its development need to be recognised in order to exercise influence on them and thus incite development of the broadband Internet access. For that purpose the linear regression model was analysed and the broadband penetration rate, a crucial indicator of the broadband Internet access, was chosen as the dependant variable. The model includes only three of the six potential explanatory variables. The three variables at the 5% significance level significantly influence variations of the dependant variable. The regression analysis of data for the European Union countries (observations for Slovakia were left out which proved to be influential) and Croatia for 2010 was performed using software packages SAS Enterprise Guide 4.3 and EViews6. The regression model was estimated using the stepwise least squares forward selection method. The conducted diagnostic tests have shown that all initial hypotheses on the model were fulfilled. The proportion of frequent Internet users has the most significant influence on the dependant variable. Since that variable is positively correlated with the broadband penetration rate, it is necessary to incite an increase in demand for the broadband Internet access. Furthermore, the results of the regression analysis indicate that the increase of the proportion of the urban population positively influences the development of the broadband Internet access, and that the price of the wholesale service of the unbundled access to the local loop is expressed in relation with the gross national income and is statistically negatively correlated with the broadband penetration rate. It can be concluded that the reduction of the share of the wholesale price in the available income results in an increased demand and use of the named service. In that way the competition at the broadband Internet access market would increase leading to the increase in the demand of end users for the broadband Internet access service.

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